Optimising the demand of a mine water reticulation system to reduce electricity consumption

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ABSTRACT

Title: Optimising the demand of a mine water reticulation system to reduce electricity consumption

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Keywords: Deep-level mine water reticulation systems, DSM, water pressure control

South Africa has some of the largest and deepest mines in the world, reaching depths greater than 3 700 m below the surface. At these depths working conditions become intolerable, with virgin rock temperatures reaching up to 60 °C. Underground temperatures must be controlled to ensure safe and acceptable working conditions for the mining personnel. This is accomplished by means of a complex water reticulation system consisting of refrigeration plants and cascaded pumping stations. The water reticulation system is used to deliver cold water to the mining levels and to pump the used hot water back to surface.

In deep-level mines the water reticulation system consumes up to 35% of the total electricity consumed by the mine. With electricity demand varying between 10 MW to 35 MW in typical deep-level mines, even a small reduction in electricity consumption will realise a significant cost saving.

Investigations into water reticulation systems at different mines have shown that water usage varies between 1.25 kl and 4.15 kl per ton of rock mined. This large variation in the water consumed per ton of rock mined indicates that some mines may be using water inefficiently. Various energy efficiency methods have been implemented to reduce electricity consumption on mine water systems. Most of these are costly and time consuming. Very few of these methods addressed the problem of mine water wastage.

Three techniques were identified which could reduce water wastage and consequently water consumption of deep-level mines. These techniques include leak management, stope isolation control and supply water pressure control. Initially the pressure control technique was tested at a typical deep level gold mine. A daily reduction of 1.4 Ml water was achieved which resulted in an estimated daily electricity reduction of 9.6 MWh. A total cost saving of R513 700 per annum is possible.

The outcome of the test conducted on Mine 1 led to the implementation of all three water reduction techniques on a different mine. Leak management realised a total daily reduction of 7 Ml with an additional reduction of 1.6 Ml per day possible from stope isolation and pressure control. An average daily electricity reduction of 92 MWh was achieved. This relates to an estimated cost saving of R5 617 000 per annum.

Further investigations revealed that a combined daily electricity reduction of 170 MWh can be achieved by implementing water reduction techniques on five other mines. This relates to an estimated financial saving of R13 120 000 per annum.

SAMEVATTING

Tittel: Optimalisering van die aanvraag van n myn water retikulasie stelsel om elektrisiteits verbruik te verminder.

Outeur: André Botha

Promotor: Dr J.F. van Rensburg

Keywords: Diep-vlak mynbou water netwerk stelsels, DSM, water druk beheer.

Suid-Afrika spog met van die grootste en diepste myne in die wêreld wat tot so diep as 3 700 m onder die aardoppervlak kan strek. Temperature by hierdie dieptes kan to 60 °C bereik. Om 'n veilige werksomgewing te handhaaf moet die ondergrondse temperature deurentyd beheer word. Dit word gedoen deur van komplekse mynwater-retikulasie stelsels gebruik te maak wat bestaan uit verkoelingstelsels, pompstelsels en kaskade damme.

Hierdie mynwater-retikulasiestelsels kan verantwoordelik wees vir tot soveel as 35% van die myn se totale elektrisiteitsverbruik. Die elektrisiteitsaanvraag van mynwater-retikulasiestelsels van diepvlak myne wissel tussen 10 MW tot 30 MW.

Ondersoeke op die mynwater-retikulasiestelsels van verskillende myne het getoon dat die waterverbruik wissel tussen 1.25 kl en 4.15 kl per ton rots wat gemyn is. Hierdie groot variasie in die water verbruik per ton rots gemyn, dui op ondoeltreffende verbruik by baie myne. Hoewel daar al verskeie energie doeltreffendheids projekte op mynwater-retikulasiestelsels geloods is, spreek min van hierdie projekte die vermorsing en ondoeltreffende verbruik daarvan aan.

Gedurende hierdie studie is drie tegnieke geïdentifiseer om die vermorsing van water en gevolglik waterverbruik van diepvlak myne te verminder. Hierdie tegnieke sluit lekkasie bestuur, "stope" isolasie beheer en waterdrukbeheer in. Die waterdrukbeheer tegniek is aanvanklik getoets op 'n tipiese diepvlak goudmyn. 'n Daaglikse afname van 1,4 Ml water is bereik wat gelei het tot 'n geskatte daaglikse elektrisiteitsvermindering van 9,6 MWh. Dit herlei tot 'n totale koste besparing van R513 700 per jaar.

Die uitkomste van die toets wat gedoen is op Myn 1 het gelei tot die implementering van al drie die waterverminderings tegnieke op 'n ander myn. Die bestuur van lekkasies het 'n totale daaglikse afname

van 7 Ml meegebring met' n bykomende afname van 1.6 Ml per dag moontlik deur “stope” isolasie en waterdrukbeheer. 'n Gemiddelde daaglikse elektrisiteitsvermindering van 92 MWh is bereik. Dit herlei na 'n beraamde koste besparing van R5 617 000 per jaar.

Verdere ondersoeke het aan die lig gebring dat 'n gesamentlike daaglikse elektrisiteitsvermindering van 170 MWh bereik kan word deur die implementering van waterverminderings tegnieke op vyf ander myne. Dit herlei na 'n geraamde finansiële besparing van R13 120 000 per jaar.

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ABBREVIATIONS

3CPFS	Three Chamber Pipe Feeder Systems
BAC	Bulk Air Cooler
CRCED	Centre for Research and Continued Engineering Development
DSM	Demand Side Management
ECS	Energy Conservation Scheme
EGM	Energy Growth Management
ESCo	Energy Services Company
F	Flow
GW	Gigawatt
GWh	Gigawatt-hour
kPa	Kilopascal
kW	Kilowatt
kWh	Kilowatt-hour
m^3/h	Cubic Metre per Hour
m^3/s	Cubic Metre per Second
mm	Millimetre
mm/s	Millimetre per Second
MPa	Megapascal
MW	Megawatt
MWh	Megawatt-hour
NERSA	National Energy Regulator of South Africa
OLE	Object Linking and Embedding
OPC	Object Linking and Embedding for Process Control
P	Pressure
PCP	Power Conservation Programme
PDA	Personal Digital Assistant
PLC	Programmable Logic Controller
PRV	Pressure-reducing Valves
R	Rand
RIO	Remote Input/Output Device
SCADA	Supervisory Control and Data Acquisition
SP	Set-Point
TOU	Time of Use
VRT	Virgin Rock Temperature
WSO	Water Supply Optimisation

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CHAPTER 1 : INTRODUCTION

1.1 ELECTRICITY OVERVIEW OF SOUTH AFRICA

The state-owned enterprise Eskom is the supplier of approximately 95% of electricity consumed in South Africa [1]. A reliable source of electricity supply is critical to ensure sustainable economic growth. Eskom has a nominal generating capacity of 44 193 MW placing it within the ten largest electricity generating utilities in the world [1].

Coal-fired power stations generate approximately 37 773 MW, or nearly 85.5% of South Africa's electricity supply. The remaining 14.5% is obtained from gas/liquid fuel turbine stations; the Koeberg nuclear power station; hydro-electric storage dams; and an almost insignificant 3 MW from wind energy [1]. Figure 1-1 shows the percentage contribution of the various different generation sources utilised by Eskom.

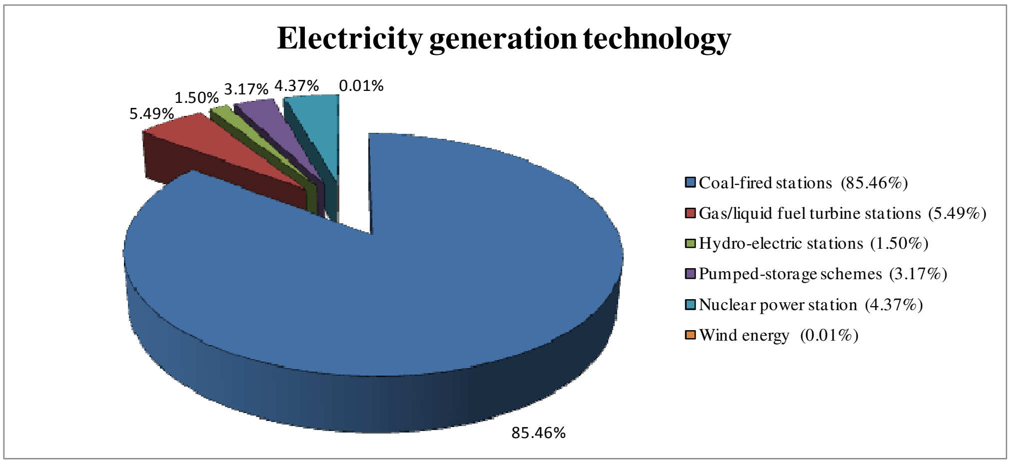


Figure 1-1: Electricity generating technology (adapted from [1])

The internationally accepted standard for a safe electricity supply reserve margin is 15% of the maximum demand [2]. The rapidly increasing demand as well as the underinvestment in new generating facilities the last 20 years have drastically reduced the South African reserve margin [3], [4]. The reserve margin decreased from a safe 20% in 2004 to a dangerously low 5% in 2008 [1], [5].

South Africa experienced frequent electricity supply failures during the last quarter of 2007. This was followed by scheduled load-shedding during 2008 to prevent a total collapse of the national grid [4], [6].

A Power Conservation Programme (PCP) was introduced as a means to reduce the high electricity demand [1].

The PCP can be categorised into three initiatives, namely [1], [7]:

- Energy Conservation Scheme (ECS)
- Energy Growth Management (EGM)
- Trading of the right-to-consume (RTC)

Steep electricity tariff increases further emphasised the need to use electricity more efficiently. The National Energy Regulator of South Africa (NERSA) has approved electricity tariff increases of approximately 25% per year for three consecutive years (2009–2011) [8].

A total of approximately 16% of the electricity sold by Eskom during 2009 was to the mining industry which makes up only 0.03% of its customers [1]. The mining industry will therefore be greatly affected by the tariff increases and PCP. The average electricity consumption of the mining industry per client is approximately 28 GWh per year. The electricity consumed in South Africa during 2006 by the respective sectors is shown in Figure 1-2 [9].

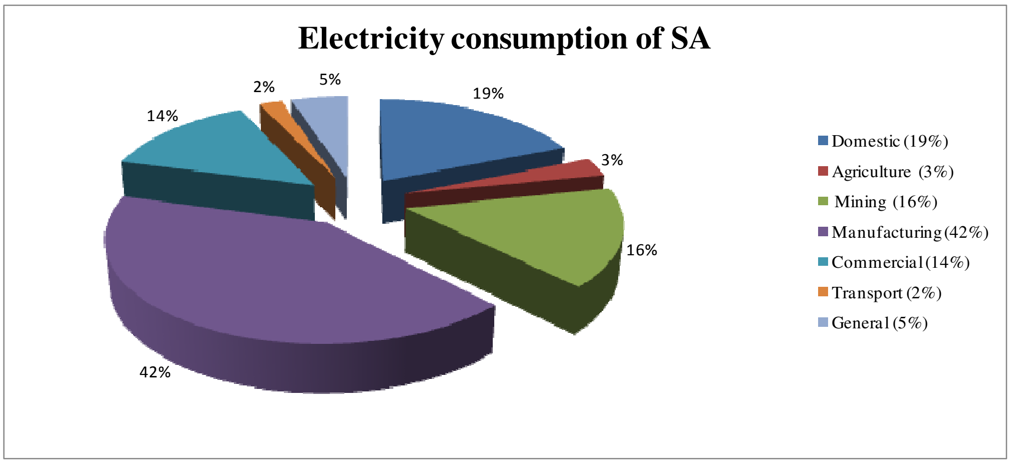


Figure 1-2: Electricity consumed per sector (adapted from [9])

1.2 ELECTRICITY CONSUMPTION IN THE MINING INDUSTRY

Extracting minerals is an energy intensive process [10]. Gold and platinum mining in South Africa is responsible for approximately 47% and 33% of the total electricity consumed by the mining industry respectively [11].

South Africa is host to some of the world's deepest mines, reaching depths greater than 3 700 m below the surface [12]. One of the major concerns when mining at these depths is the high ambient temperatures as virgin rock temperatures could exceed 60°C [13], [14].

Ventilation and cooling in deep-level mining is of paramount importance to ensure a safe working environment. The use of air ventilation alone becomes less effective as the depth of mines increase partly due to the air being heated through auto-compression. This led to the use of water as a medium to extract heat from the mine [13], [15].

Refrigeration plants; underground chilled water supply; and the underground dewatering system all form part of the complete water reticulation system. Figure 1-3 shows the breakdown of the average electricity consumption of typical deep-level mining processes. The data used to calculate the breakdown was obtained from two gold mining groups in South Africa [16], [17]. Only the main pumping, compressors, refrigeration plants and winders are categorised individually, the Mining category includes small booster pumps, winches, underground lights etc. Office blocks and hostels are included under the Other category.

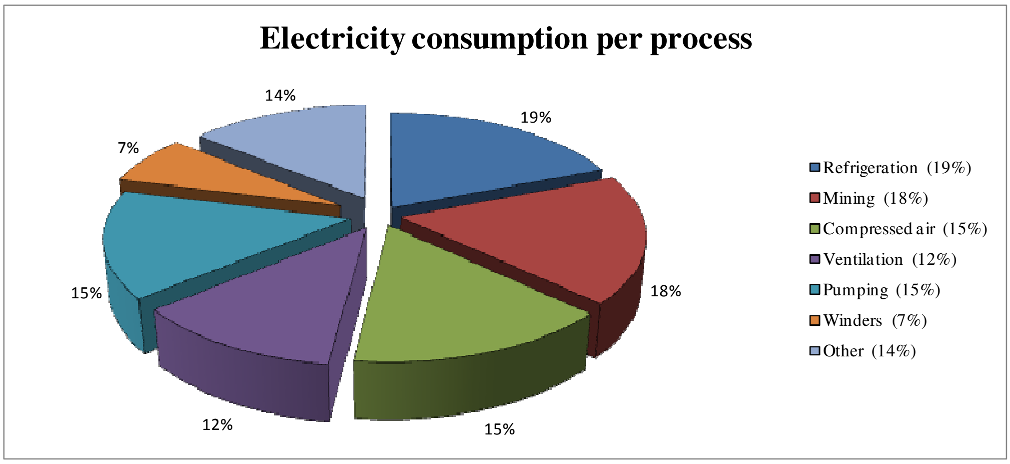


Figure 1-3: Average mine process electricity consumption (adapted from [16], [17])

The water reticulation system, associated with production (drilling and sweeping) and cooling (cooling cars etc.), is responsible for a large portion of the total electricity usage of the mine. A typical mine can on average pump between 15 000 kl to 25 000 kl water daily from underground to the surface.

1.3 DEMAND SIDE MANAGEMENT INITIATIVES IN THE MINING INDUSTRY

A tried and trusted short-term method to increase electricity supply reserves is demand side management (DSM). This is the term used for the planning and implementation of activities used for altering or manipulating the electricity load profile or load shape at the end-user's side [18]. DSM could entail load shifting, peak clipping, or overall electrical energy efficiency as discussed below.

Load shifting

Load shifting refers to the practice where the electrical load is reduced during a peak demand period. The total electrical energy consumed daily will remain unchanged. A typical load-shift profile is shown in Figure 1-4 where the area under the graph represents the energy consumed.

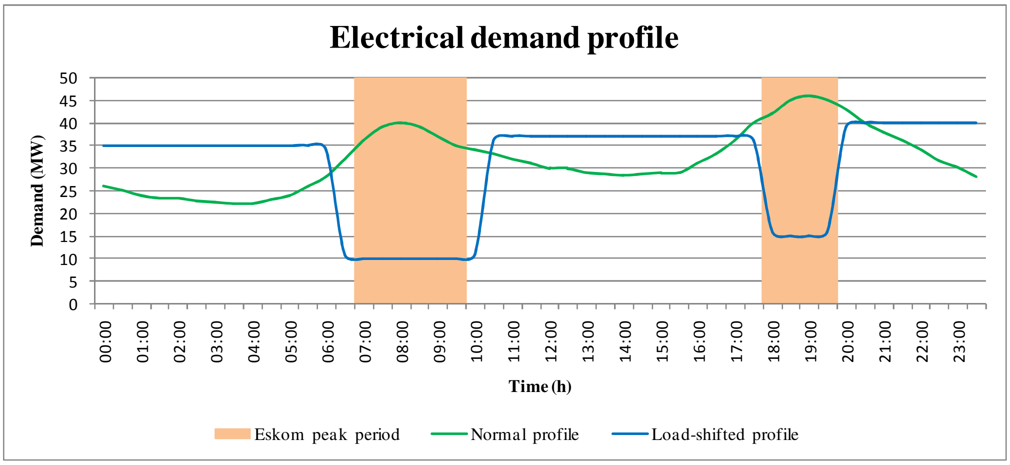


Figure 1-4: Typical load-shift profile

Peak clipping

Peak clipping refers to the practice where the peak, or maximum, demand is reduced. The load is altered by switching off, or stopping, a process or system. This will reduce the total electricity demand and consumption but could also halt or reduce production. Although the peak (or maximum) demand can occur during any period, peak clipping is usually done during the Eskom peak period. Figure 1-5 depicts a typical peak-clipping load profile.

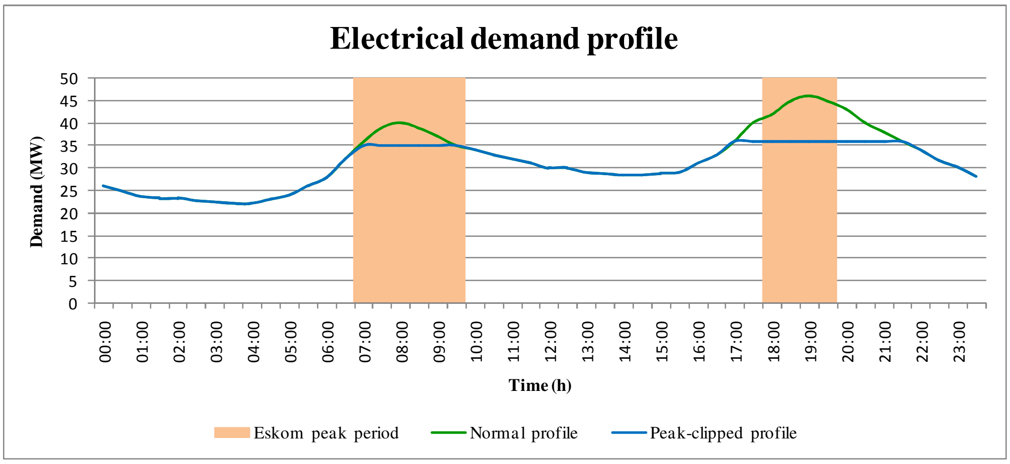


Figure 1-5: Typical peak-clipping profile

Energy efficiency

Energy efficiency (also known as strategic conservation) refers to the practice where electricity is used more efficiently. This could be due to either more efficient equipment being utilised, or changing to a more efficient process. A typical energy-efficiency load profile is shown in Figure 1-6.

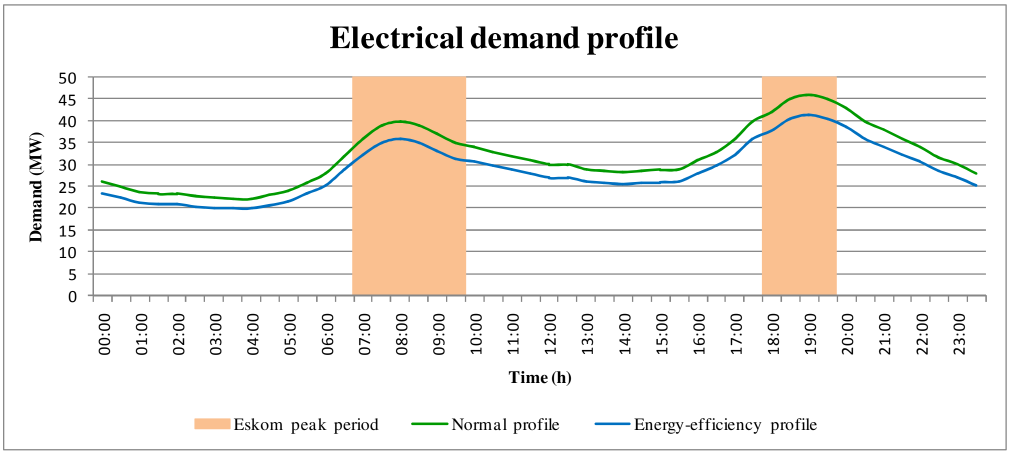


Figure 1-6: Typical energy-efficiency profile

Due to the large energy consumption the mining industry offers great potential for DSM opportunities. Energy Services Companies (ESCos) in South Africa as contracted by Eskom have successfully implemented various DSM projects in the mining industry [19].

It is estimated that the implementation of these projects at deep-level gold and platinum mines have already realised total electricity savings of 200 MW [20]. Some of the DSM initiatives implemented on the water reticulation system of South African mines are briefly discussed:

Dewatering pump system

Used water needs to be extracted from the mine. This is accomplished by means of the dewatering pump system. Load shifting on the dewatering pumps is achieved through the automated control of the pumps and the optimal utilisation of the capacities of the cascading storage dams. During a study conducted by Rautenbach a total of 39.48 MW load was shifted from the Eskom evening peak periods on the pumping systems of eight mines [21].

Energy efficiency is achieved through energy recovery initiatives. Turbine generators and Three Chamber Pipe Feeder Systems (3CPFS) are installed to recover some of the hydraulic energy of the supply water. This energy is then used as free pumping energy [22].

Refrigeration system

The refrigeration system also offers load-shifting capabilities. This can be achieved by optimally utilising the thermal storage capacity of the refrigeration system [23], [24]. Load is successfully shifted to off-peak periods through implementation of automated control on the refrigeration plants [23].

Underground refrigeration plants contribute to energy consumption reduction on the dewatering system. This is because not all the water has to be pumped to the surface for cooling. The disadvantages in using this approach include maintenance complexity and cooling efficiency.

Water consumption can be reduced by using ice as a cooling medium. The cooling capacity of ice reduces the amount of water needed to achieve the same amount of cooling [14]. This will result in the dewatering system pumping less water.

Although there are large financial benefits from these approaches they do not positively impact the water misuse and wastage; implementation could be complex and costly; and implementation may take a long time.

1.4 GOALS OF THE STUDY

The objective of the study is to investigate and develop a strategy to optimise the water demand of a deep-level mine water reticulation system to reduce its electricity consumption. This will be achieved by accurately matching the supply to the demand.

Implementation on two deep-level gold mines will serve as case studies to demonstrate the practicability and benefits of this approach.

1.5 OUTLINE OF DISSERTATION

Chapter 1

Chapter 1 gives a brief background on the electricity generation and consumption in South Africa. The problem statement and need for the study is set and motivated.

Chapter 2

Chapter 2 serves as a literature review for the study. The mine water reticulation system and operations are described in more detail. The water supply, demand and pumping systems are discussed along with a more in-depth look at alternatives applied to the water system of a mine. This initiative and its importance are also motivated in Chapter 2.

Chapter 3

In Chapter 3 the optimisation of the water reticulation system is investigated and the savings obtained are quantified.

Chapter 4

In Chapter 4 the implementation and results of the study are discussed. Two mines were used as case studies to test the water reticulation optimisation methods.

Chapter 5

Chapter 5 is used to conclude the outcome of the study. Recommendations are made regarding further work.

CHAPTER 2 : DEEP-LEVEL MINE WATER RETICULATION SYSTEMS

2.1 PREAMBLE

As mentioned in Chapter 1 South Africa is host to some of the deepest mines in the world. The mining industry requires intricate water reticulation systems in order to maintain a safe working condition at these depths. The water reticulation can be divided into two basic categories: the refrigeration and distribution; and the dewatering system. Figure 2-1 depicts a typical water cycle of a deep-level mine [25].

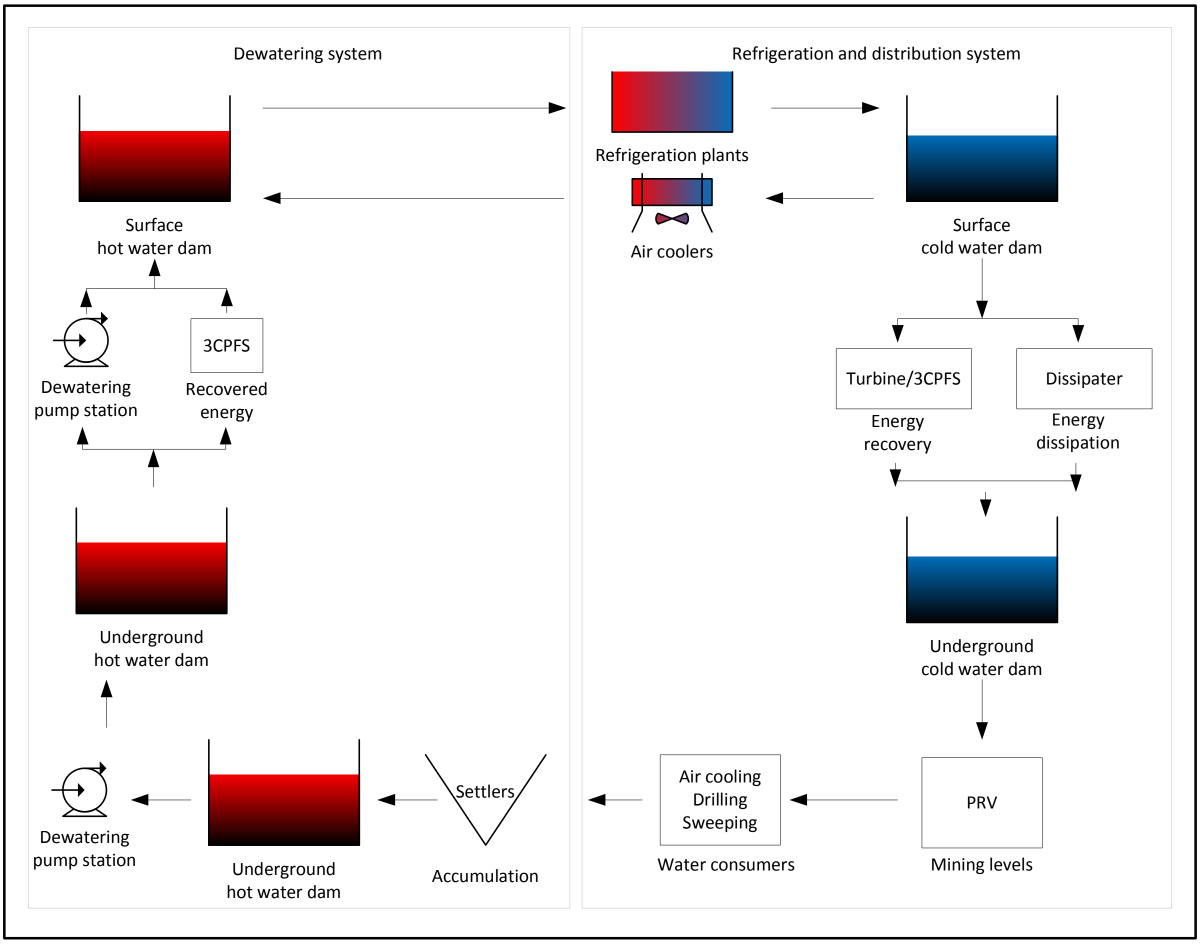


Figure 2-1: Typical deep-level mine water cycle

2.2 WATER SUPPLY AND DEMAND

Water is used for various tasks in the mining industry. Water was initially used for dust suppression after blasting took place and during the drilling shifts. However, cooling is one of the most vital roles of water in deep-level mining today [13], [15]. This is due to the depths reached and the virgin rock temperature (VRT) present at these depths.

The VRT in South Africa increases by approximately 12 °C per kilometre of vertical depth depending on the region in which the mine is located [15]. Figure 2-2 below illustrates the increase of VRT at different regions in South Africa as the depth below surface increase [14].

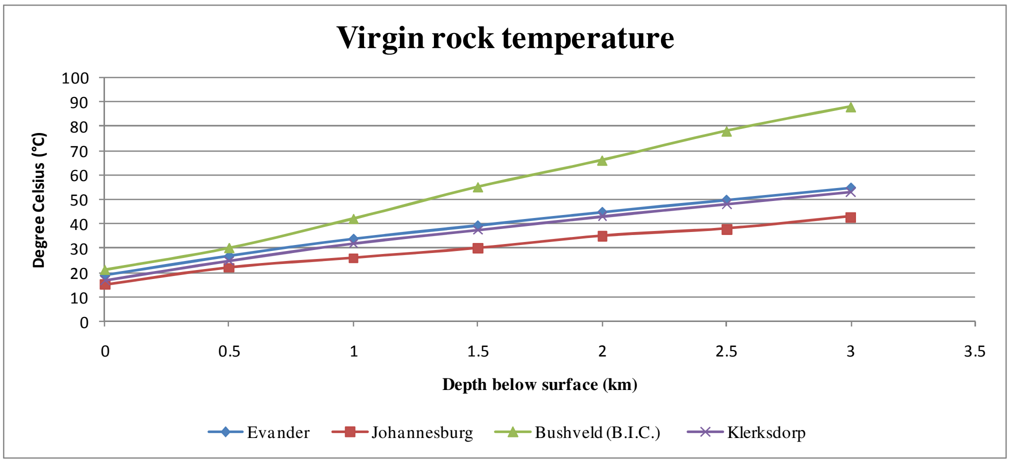


Figure 2-2: Virgin rock temperature (VRT) (adapted from [14])

With VRT reaching temperatures as high as 60 °C cooling becomes an engineering challenge. Wet-bulb temperatures above 32.5 °C become unsafe and could lead to heat cramps, heat stress or even heatstroke. The standard is to keep the wet-bulb temperature below 28 °C for all working areas [26], [27].

The water supply system of a deep mine consists of the refrigeration system; surface and underground chilled water storage dams; energy recovery systems; and energy dissipating equipment. A simplified layout of a typical deep mine water supply system is shown in Figure 2-3. The components are discussed in the following sections.

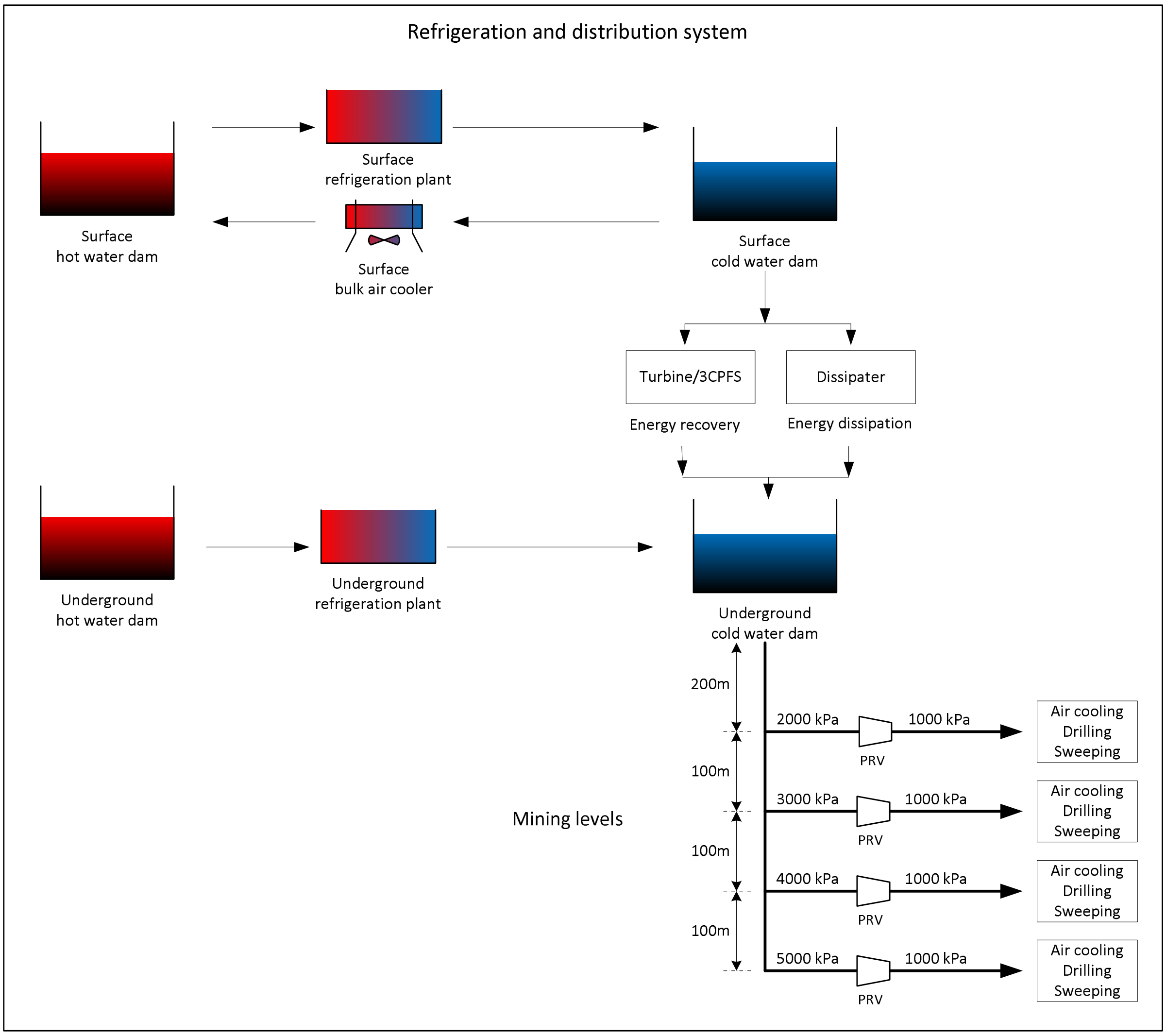


Figure 2-3: Simplified deep-level mine water supply system

2.2.1 REFRIGERATION

Water is cooled by refrigeration systems — usually situated on the surface — to temperatures ranging between 3 °C to 5 °C. The cooled water is circulated through heat exchangers or air coolers. Air is passed over the heat exchangers for the water to absorb the heat from the air. These heat exchangers come in the form of large bulk air coolers (BACs), and smaller spot coolers and cooling cars.

The BACs can be situated on the surface as well as underground. The BAC is used to cool down the air that is circulated for ventilation throughout the mine. Cooling cars and spot coolers are situated closer to the working areas to cool the air that enters the working area [14].

Underground refrigeration plants are commonly used when the surface refrigeration system becomes insufficient.

Some of the advantages of underground refrigeration systems are [28]:

- Less heat gain to the chilled water from the main shaft as the distribution distance is less.
- Reduced dewatering pumping cost as only excess water has to be pumped back to the surface.

Some of the disadvantages in using underground refrigeration systems are [28]:

- Extensive excavation required for underground installation.
- High operating costs due to high condensing temperatures.
- Maintenance is difficult and costly as a result of underground location.

Ice plants are also used to cool down the service water at some mines. When compared to the same mass of chilled water, ice produces better cooling resulting in up to five times less water required [28], [29]. Some disadvantages in using ice as a cooling medium are the capital and operating costs, as well as the transportation challenge of the ice slurry [30].

2.2.2 DISTRIBUTION

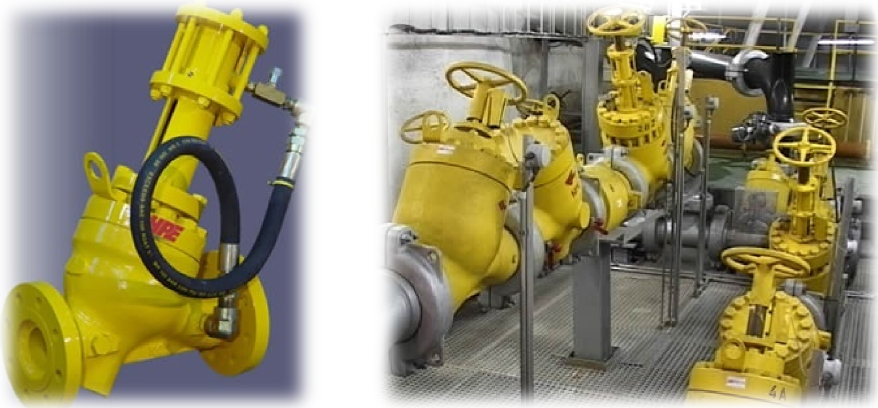
Water is stored in chilled water storage dams on the surface. This is because of the varying water demand as a result of different mining activities. These storage dams create the potential benefit of thermal storage which can be utilised for load shift as mentioned previously.

From the surface storage dam water is gravity-fed to the working areas via an intricate piping network. Due to the depth of the mine extreme hydraulic pressures are exerted by the fluid. These pressures become dangerously high and difficult to distribute safely. In some mines the water pressure can be as high as 10 MPa.

The water pressure is reduced by means of dissipaters, pressure-reducing valves (PRV) and underground cascading dams which acts as pressure-breaking dams [15]. Cascading dams have a dual purpose as it serves as a means of pressure reduction as well as storage for high water demand periods. One disadvantage of underground water storage is the increase in water temperature, reducing the cooling capabilities [13]. The chilled water supply columns should be sufficiently insulated to avoid further temperature increases [31].

PRVs reduce the water pressure of the supply water to a safe workable pressure by converting the hydraulic energy into thermal energy [32]. This also results in an increase in the water temperature. Some PRVs have fixed preset pressure drops over the valve and cannot be changed easily. The downstream pressure varies with a change in the upstream pressure. Modern self-regulating PRVs ensure a constant downstream pressure independent of a fluctuating upstream pressure.

PRVs are usually situated on each level near the main water supply column. In some cases — depending on the type of valve used and the required total pressure drop — multiple valves are used in series to form a pressure-reducing station. This results in smaller differential pressures over each valve which decreases the potential for cavitation as is explained in Section 2.4.2. A typical pressure-reducing station is shown in Figure 2-4 [33].



(a) PRV (b) PRVs used in a pressure-reducing station

Figure 2-4: Pressure-reducing valve station [33]

Some mines make use of energy recovery systems in the form of impulse turbines as part of their water supply reticulation. The supply water is fed through a pelton wheel turbine which is coupled directly to an induction generator. The water flow velocity is determined by the average water demand. This energy recovery system will reduce the 24-hour average load profile by the generating capacity of the generator [34].

Impulse turbines could also be coupled directly to the shaft of a dewatering pump to serve as the driving agent. Energy recovery of up to 67% can be achieved through this configuration [34]. Another benefit of using pelton wheel turbines as a means of energy recovery is that it reduces the amount of water temperature increase obtained as a result of water pressure dissipation [28].

2.2.3 CHILLED WATER CONSUMERS

Chilled water is used as service water because of its cooling benefits. It was found that by cooling the service water the wet-bulb temperature at the face in working stopes is reduced [35], [36]. Some of the typical uses of water in the underground working areas are:

Cooling

Cooling cars and spot coolers usually consist of a radiator through which the chilled water flows. Figure 2-5 shows a typical cooling car used in the mining area. Warm air is blown into the cooling car on one side and passes over the radiator. Heat exchange takes place and the air exits on the other side of the cooling car as cold air.

Figure 2-5: Cooling car [37]

Water jetting

High-pressure water cannons and water jets are used to move the fine broken rock during stope cleaning or sweeping. This reduces the need to use scraper winches, brushes and shovels to move the broken rock to the loading areas [15], [29]. Figure 2-6 displays a water cannon and a high-pressure water jet used in the mining industry [38].

(a) High-pressure water jet (b) High-pressure water cannon

Figure 2-6: Water used to move fine broken rock [38]

Drilling

Water is used for cooling the drill bit, as well as a means of suppressing the dust created by the drilling action. Some mines also make use of hydropowered drills where water is used as a medium to power the drilling action. A typical drill used in the deep-level mining industry is shown in Figure 2-7.

Figure 2-7: Water used for drilling

Water spray

After blasting has occurred, water spray is used for dust suppression as well as to rapidly cool the area to allow mining personnel to re-enter [13]. The rock face is also hosed off with the service water as shown in Figure 2-8.

Figure 2-8: Water used to cool the rock surface

The used service water, along with other fissure water or groundwater, must be extracted from the mine. This is accomplished using the mine's dewatering system as discussed in the following section.

2.3 THE DEWATERING SYSTEM

The dewatering system of a deep mine consists of settlers, hot water storage dams, dewatering pump stations and other free energy dewatering systems. Figure 2-9 shows a simplified layout of a typical deep-level mine dewatering system. These components are discussed in the following sections.

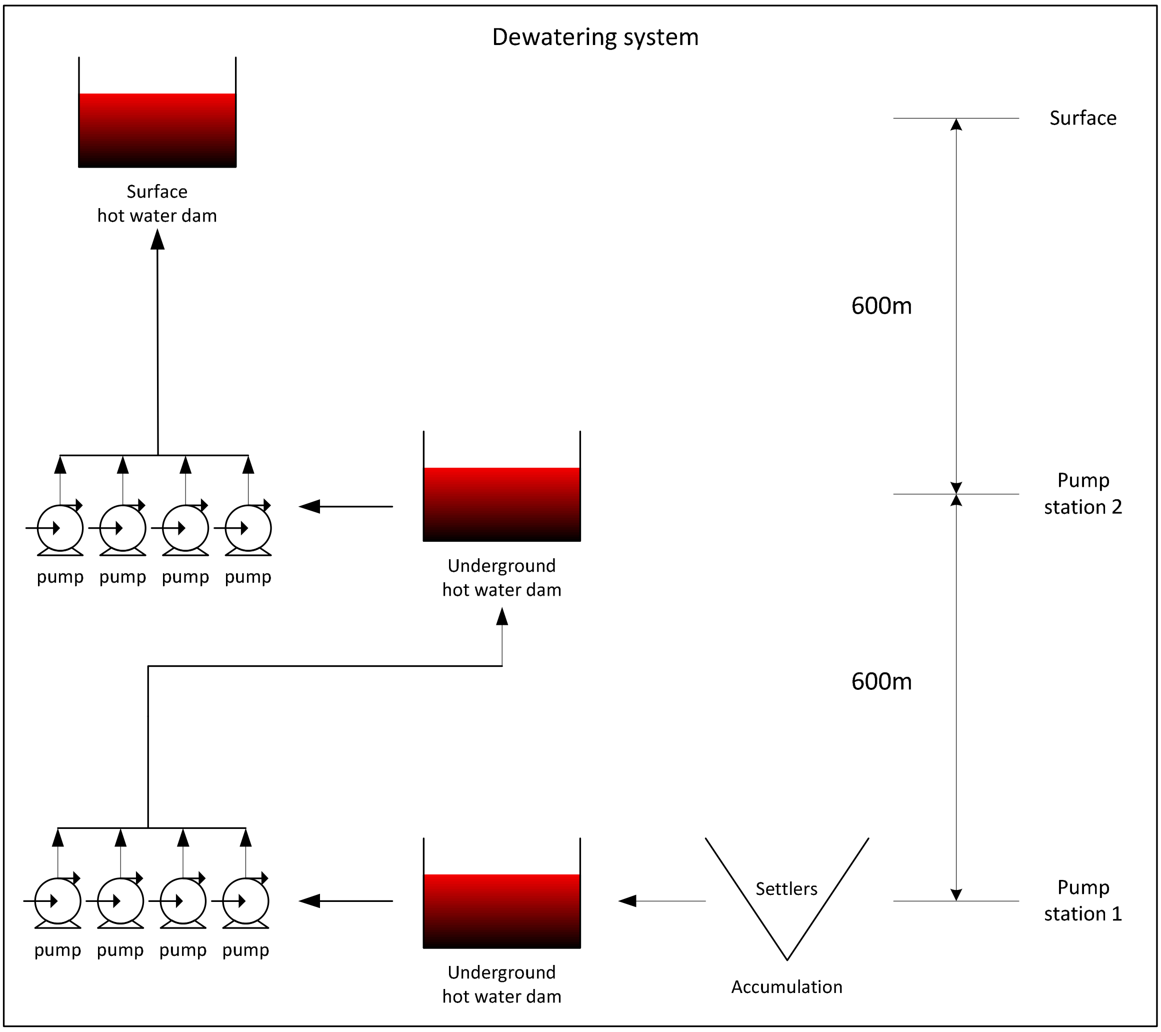


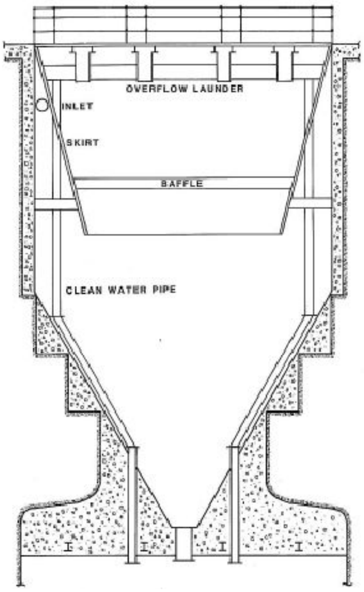
Figure 2-9: Simplified deep-level mine dewatering system

The power consumption data for 2009–2010 of several deep gold mines in South Africa was analysed. From this data it was concluded that on average the dewatering system accounts for approximately 15% of the total electricity consumption of the mine [16].

2.3.1 ACCUMULATION AND SETTLING

The used service and cooling water, also referred to as run-off mine water, is channelled to the settlers where the clear water is separated from the mud. The separators in the settlers work on the principle of a flocculent being added to the water and then allowing the particles formed to settle at the bottom of the settler.

The flocculent is added to the run-off mine water in a feed launder while the fluid is in a laminar flow. The settled particles, or sludge, are drawn off at the bottom of the settler into mud dams. The clean water overflows into the skirt of the settler and through clean water pipes into the hot water dams. A cone settler is shown Figure 2-10 [32], [39].



(a) Cutaway drawing of a settler

(b) Image of a typical mine settler

Figure 2-10: Deep-level mine underground settler [32], [39]

2.3.2 PUMPING

The mud is pumped from the mud dams via the mud pumps towards the surface where it will be processed to retrieve the mineral deposits it contains. The mud pumps are small compared to the dewatering pumps and therefore not included in this study. The clear water is pumped from the hot water storage dam using the dewatering system. Because of the depth of some mines the dewatering system usually consists of multiple cascaded pumping stations.

Typical deep-level gold mines in South Africa have pump stations on intervals ranging from 600 m (Tshepong gold mine) to more than 1 000 m (Kopanang gold mine) [40]. It has been shown that the most economical vertical distance between pump stations is at approximately 600 m intervals [41].

Water is pumped from the lower-level hot water storage dam into the upper-level hot water storage dam. This process is repeated until the water reaches the surface hot water storage dams. If the storage dams have adequate storage capacity, significant electricity cost savings can be achieved through load shifting as was described in Chapter 1.

The dewatering system of deep-level mines usually incorporates large multistage centrifugal pumps [41], [42]. This is due to the extreme height that the water must be pumped. A centrifugal pump which consists of more than one impeller is referred to as a multistage centrifugal pump (No further information on the types and characteristics of these pumps are required for this study).

The water that exits the discharge end of the first impellor, or stage, enters the suction end of the next impeller. Each stage develops a certain amount of head which adds up to form the total head produced by the multistage pump [43]. The total pressure head may be estimated by adding 5–10% to the static head to allow for friction forces [41].

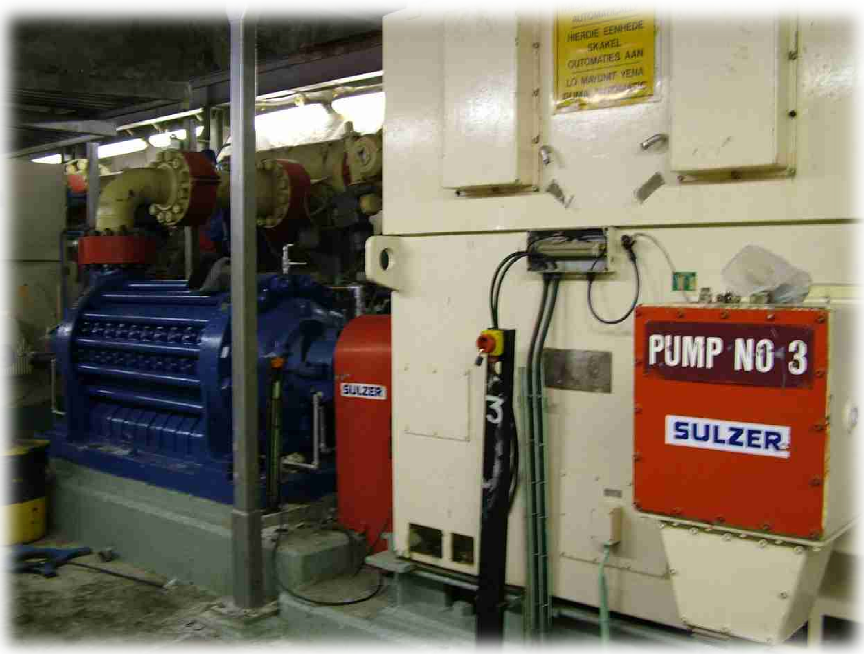


Figure 2-11: Multistage centrifugal dewatering pump

The efficiency of the dewatering systems varies from one mine to the next depending on the pump and pipe network arrangements. The pumps of a level pumping station usually feed off a common supply manifold. The pumps on a pump station at a specific level operate in parallel and can therefore be controlled according to the volume of water to be pumped out.

When multiple pumps are operated into a single discharge column the flow rate of the water increases with the addition of each pump. The increase in flow rate results in an increase in friction force and therefore an increase in total pressure. This results in the pumps operating at a higher discharge pressure which decreases the efficiency of the pump.

This is shown in Figure 2-12 [32].The flow rate contribution of each pump decreases significantly compared to what the pumps can deliver if they are operated individually. It will therefore be beneficial to determine the maximum number of pumps the discharge column can handle and control the pumps accordingly. Some mines may have more than one column installed on their dewatering reticulation to avoid this effect.

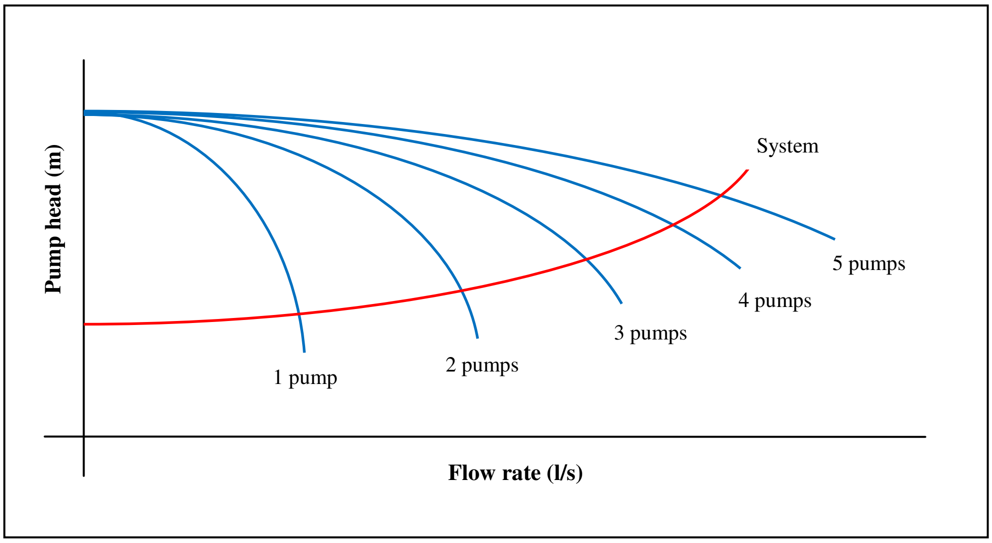
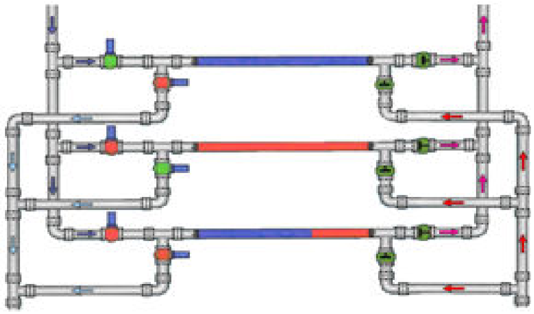


Figure 2-12: Flow contribution of multiple pumps operating in parallel (adapted from [32])

Some deep mines also introduced Three Chamber Pipe Feeder Systems (3CPFS) which act as free energy dewatering systems. The 3CPFS works on the principal of a U-tube where the hydrostatic pressure of the chilled supply water is used to balance out the hot water of the dewatering system [34].

The advantage of a 3CPFS is that the only energy required to pump the water to the surface is the amount of energy required to overcome the friction losses of the system. To achieve this, smaller booster pumps and a series of valves are used. A schematic of the operation of a 3CPFS; and a 3CPFS installed at a deep mine is shown in Figure 2-13 [22], [27].



(a)3CPFS operation

(b) 3CPFS installed at a mine

Figure 2-13: Three Chamber Pipe Feeder System [22], [27]

Some of the disadvantages associated with the 3CPFS are listed below [28], [34]:

- The installation of the units requires relatively large excavation.
- A standby or bypass pumping system should be in place to operate in the event of any failure of the 3CPFS which could be costly.
- The 3CPFS can only operate adequately if there is a chilled water demand underground while at the same time hot water is available for extraction to surface.

2.4 VALVES AND INSTRUMENTATION

Valves are widely used in the mining industry and in various applications. In this section only valves used in water supply-related applications will be considered. Valves can be described as a mechanism used to alter the flow and/or pressure of a fluid in a system. Devices commonly used in conjunction with a valve, if a specific flow or pressure is desired, are flow meters, pressure transmitters, actuators and controllers — such as Programmable Logic Controllers (PLC). These devices are discussed in the following section.

2.4.1 VALVE CHARACTERISTICS

Valves are used to alter the pressure and flow of a fluid. This is accomplished by means of restrictions within the valve to create friction losses. It is important to select the valve type and size according to the application requirements and constraints. Different types of valves produce different flow characteristics when opening or closing.

Valves are selected according to the fluid pressure, flow rate and flow characteristic required. The standard flow characteristics found in valves are shown in Figure 2-14 [44].

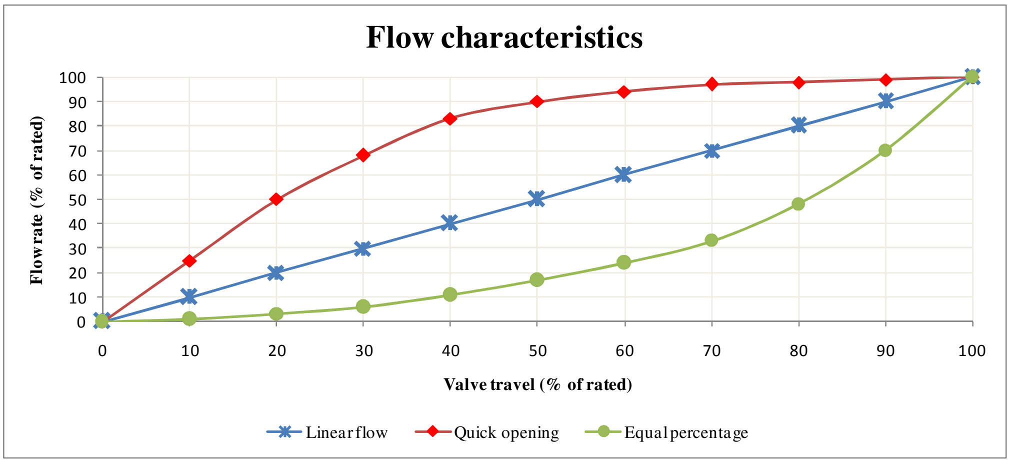


Figure 2-14: Typical valve flow characteristics (adapted from [44])

<u>Linear flow</u>

A valve is said to have a linear flow characteristic when the percentage valve opening will produce an equivalent percentage of the maximum flow. For example, when the valve is 25% open the flow rate will be 25% of the maximum flow. The flow rate is said to be directly proportional to the valve travel [44].

<u>Equal percentage</u>

A valve with an equal percentage flow characteristic produces a percentage change in flow equal to the percentage valve travel. This means that flow increments increase as the valve travel increases. In other words, there will be little change in the flow through the first portion of valve travel with an increase change as the valve opens resulting in a large flow rate increase in the final stages of valve travel [44].

<u>Quick opening</u>

A quick opening flow characteristic is almost the opposite of an equal percentage flow characteristic. During the first portion of valve travel a significant increase of flow is achieved. The change in flow rate decreases as the valve reaches the final portion of the travel [44].

2.4.2 TYPICAL VALVE PROBLEMS

<u>Cavitation</u>

Cavitation is a phenomenon which occurs in liquids when the pressure at some point drops below the vapour pressure of the liquid. The liquid at this point will vaporise (or boil) forming small vapour bubbles. Damage occurs when the vapour bubbles implode (or collapse) as pressure recovery takes place. This may produce very high pressures on the adjacent walls and component parts.

The result of cavitation is permanent damage to the interior surface of the valve caused by the imploding bubbles near the surface. The damage caused by cavitation on the plug of a valve is shown in Figure 2-15 [45].

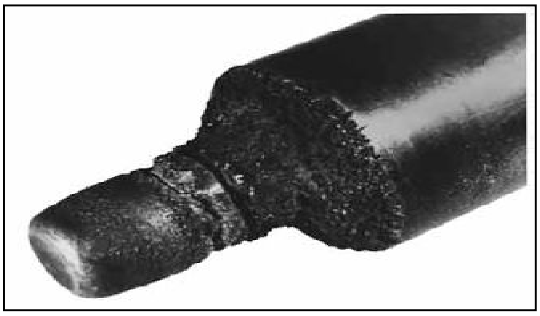


Figure 2-15: Damaged plug caused by cavitation [45]

Cavitation leads to reduced valve performance and reduced seat-sealing properties resulting in flow leakage through the valve.

Flashing

Flashing occurs when the liquid pressure is not restored above the vapour pressure of the liquid and the bubbles that were formed do not collapse. The fluid that flows at extremely high velocities contains vapour bubbles. The result is erosion to the surface which is in contact with this fluid as shown in Figure 2-16 [45].

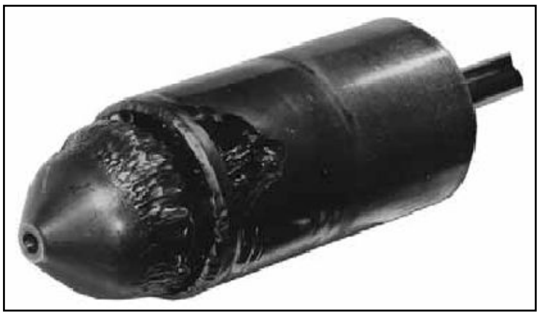


Figure 2-16: Damaged plug caused by flashing [45]

The damage caused by flashing usually occurs at, or near the seat of the valve where the velocity is at its highest and therefore the static pressure is at its lowest. This results in reduced sealing capabilities and reduced valve performance.

Noise

Noise levels are another problem that persists in valve control applications. The large velocities resulting from a partially open valve causes very large pressure drops and turbulence. This results in vibrations that induce noise in the valve and downstream piping. Noise caused by valve control is displayed in Figure 2-17 [45].

This vibration can lead to audible noise which could be damaging to human hearing. The noise levels induced by valve control should therefore be considered when the valve selection is made. The vibrations could also lead to loosening of components and be damaging to the valve and other control equipment shortening the component life [45].

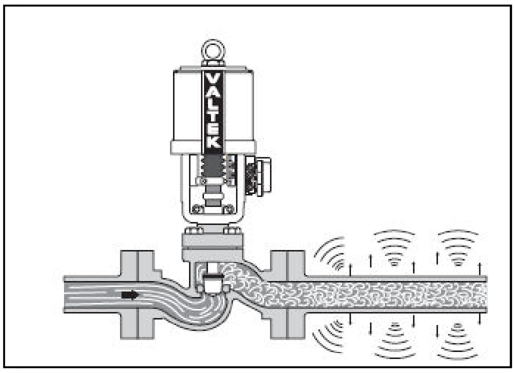


Figure 2-17: Vibration caused by turbulence [45]

Water hammer

Water hammer is a phenomenon which occurs when there is a sudden decrease in the liquid flow velocity. Pressure waves of large magnitude are generated and travel along the length of the pipe. These waves can be damaging to the piping network and downstream equipment [45], [46]. This will result in leaks or total shutdown for repairs. In the mining industry flooding of a level can occur due to burst water columns.

Figure 2-18: Damaged column caused by water hammer [47]

If the valve actuator is not sized correctly the valve plug may be sucked into the valve seat. This sudden shut-off effect, known as the 'bathtub stopper effect', could lead to water hammer. It is important to select the correct size and type of actuator to allow slow valve motion with adequate thrust to prevent water hammer [45].

2.4.3 CONTROL VALVES TYPES

Many different valves are used for control applications. Valves are selected according to the type of fluid, flow velocity and the pressure range in which control is desired. Valves are sized using a dimensionless quantity called the valve coefficient (C_v). The valve coefficient is defined as the volume of a fluid at 16 °C that will pass through a valve with a pressure drop of 100 kPa over the valve [48]. Some of the most commonly used control valves are described below.

<u>The butterfly valve</u>

The butterfly valve is widely used in various industries. The shape of the valve body makes installation simple as minimum space is required. A conventional disk butterfly valve is shown in Figure 2-19. This valve is ideal for throttling and on/off applications.

There are however some restrictions in using butterfly valves in control applications. High pressure applications and large valve sizes would require large actuators with high output power [44]. The butterfly valve has an approximate equal percentage characteristic having only a small pressure drop over the valve when fully open.

Figure 2-19: Butterfly valve [44]

One of the drawbacks of using a butterfly valve is the narrow control range. This limits the valve suitability to fixed loads [49]. Eccentric disk valves are similar to butterfly valves with the main difference being the mounting of the disk. This results in the disk being pulled away from the seal when opening, minimising seal wear and changing the characteristic of the valve to a more linear flow characteristic [49].

The ball valve

A ball valve is characterised by a small pressure drop over the valve when fully opened as it has a straight-through flow design. Figure 2-20 shows a V-notch ball valve [44]. The ball valve has an equal percentage flow characteristic and provides control over a wide pressure range. The valve has a tight shut-off capability due to the ball never leaving the seat. This valve is suitable for throttling and ideal for on/off applications.

Figure 2-20: Ball valve [50]

The major drawback of rotary-type ball and butterfly valves for control applications is their relatively fixed characteristics and susceptibility for cavitation [44], [49]. The selection of these valves becomes rather complex if reliable control is required with minimum maintenance.

Globe type valves

Globe type valves are more expensive than the previously discussed rotary type valves but in certain control applications the characteristics of these valves make them the viable choice. A single port globe valve is shown in Figure 2-21.

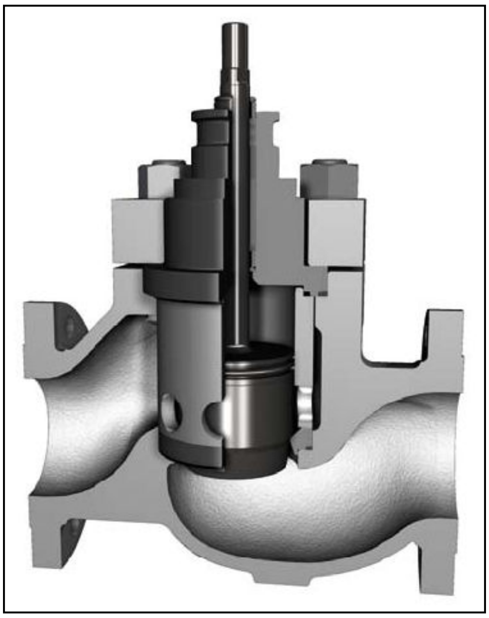


Figure 2-21: Globe valve with cage-style trim [50]

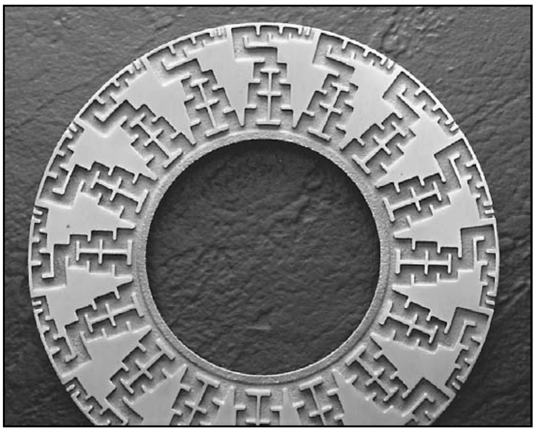
The construction of these valves allows special cages and trims used to change the characteristics and capacities of the valve [44]. Special energy-dissipating trims are used to reduce the noise and vibration usually present with high pressure valve control. Tests have proven that when using a special trim (such as the tortuous path trim), the cavitation, noise and vibration can be significantly reduced and even nullified [51].

This is ideal for high pressure and high velocity flow applications where cavitation, flashing, noise and vibration become a concern. Standard cages used in globe valves are shown in Figure 2-22.

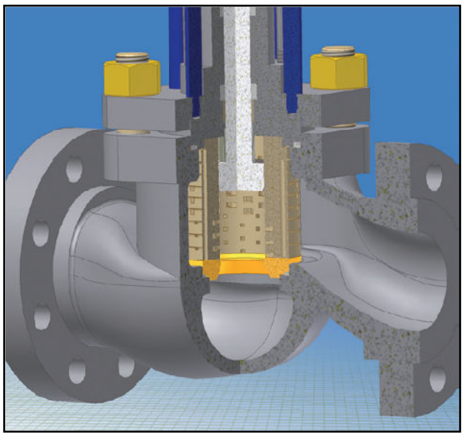
a) Quick opening b) Linear c) Equal percentage

Figure 2-22: Characterised cages for globe valves [50]

The working principle of the special trims is to create smaller pressure drop stages and thus avoiding one large pressure drop over the valve plug and seat. Stacked disks are situated around the valve plug creating multiple flow paths with different pressure drop stages. An example of a disk used in stacks to form the special trim is shown in Figure 2-23.



(a) Tortuous path disk



(b) Valve assembly

Figure 2-23: Special energy-dissipating trim [45]

Using globe valves with cage trims simplifies maintenance as the valve plug, seat, and cage can easily be replaced without having to remove or replace the whole valve. Another benefit is that restricted capacity trims can be used to reduce the flow capacity of the valve. This will be advantageous in applications where fluid flow rate decreased significantly. It would therefore not be necessary to replace the valve, instead the valve body can be used with a restricted capacity trim [44].

2.4.4 INSTRUMENTATION AND CONTROL

There are certain components required for valve control applications. These components can be categorised as controllers, actuators and feedback equipment.

Programmable Logic Controllers (PLC) are commonly used for process control. There are various models and manufacturers of PLCs. It is usually good practice to standardise on one PLC manufacturer throughout the plant. This will simplify maintenance and the connection to a Supervisory Control and Data Acquisition (SCADA) system. The PLC is used to monitor and control the process by supplying the valve positioner with a set-point to where the valve should open or close to obtain the desired output.

Valve actuators are defined as the device that converts pneumatic, hydraulic or electric power into linear or rotary motion that can apply sufficient force to open or close the valve [44]. Actuators can be set to a fail-safe position. This is the position to where the actuator will move to when actuation power is lost. Fail-safe positions are typically fail-open or fail-close depending on the system requirements [50]. Pneumatic actuators are most widely used in the deep-level mining industry due to the availability of compressed air.

Feedback instrumentation plays a vital part of the control system. In order for the PLC to control the output it requires system status information. The feedback required in typical valve control applications are:

Valve position

The valve position is obtained from a positioner situated on the valve or actuator body. Feedback can be a 4–20 mA analogue signal, or a digital signal from a limit switch.

Fluid flow

This feedback is obtained from a flow meter. There are various types of flow meters, inline- and nonintrusive-type flow meters, depending on the application and type of fluid to be measured.

Fluid pressure

The fluid pressure is measured with a pressure transmitter. The pressure transmitter can be installed upstream or downstream of the valve depending on which pressure is to be controlled by the valve.

The output of this equipment is used by the controller to calculate the error signal. The error signal is then used to determine the input signal to the valve actuator. It is important for the feedback instruments to be reliable for optimal valve control.

2.5 SUMMARY

The deep-level mine water reticulation system is a complex system consisting of refrigeration plants, heat exchangers, storage dams, pumps, valves and instrumentation. Valves play a vital role in the water reticulation system and it is important to select the correct valve and actuator for the specific application.

The incorrect valve and actuator choice could lead to underperformance, cavitation, flashing and water hammer. This could have damaging effects on the water reticulation system. The ball and butterfly valves are ideal for normal on/off applications whereas the globe valve should be used for pressure control applications.

CHAPTER 3 : OPTIMISING THE DEMAND OF A WATER RETICULATION SYSTEM

3.1 PREAMBLE

One of the simplest methods to reduce the electricity consumption of a pumping system is by reducing the amount of pumping that has to take place. This chapter serves as the discussion and development of techniques to reduce the water demand and to quantify the savings.

3.2 TECHNIQUES TO REDUCE THE WATER DEMAND

The South African mining industry offers significant potential for water supply optimisation. Large water-consuming mines can be identified by using the relationship between their water consumption and the combination of ore and rock hoisted. The combination of rock and ore is used as water consumption takes place in both production and development areas.

The water consumption and hoist data obtained from several deep-level gold mines were plotted and compared during a recent study by Vosloo [32]. From the data it could be concluded that on average the deep-level gold mining industries in South Africa require approximately 2.45 kl water to mine a ton of rock. This relationship is shown in Figure 3-1.

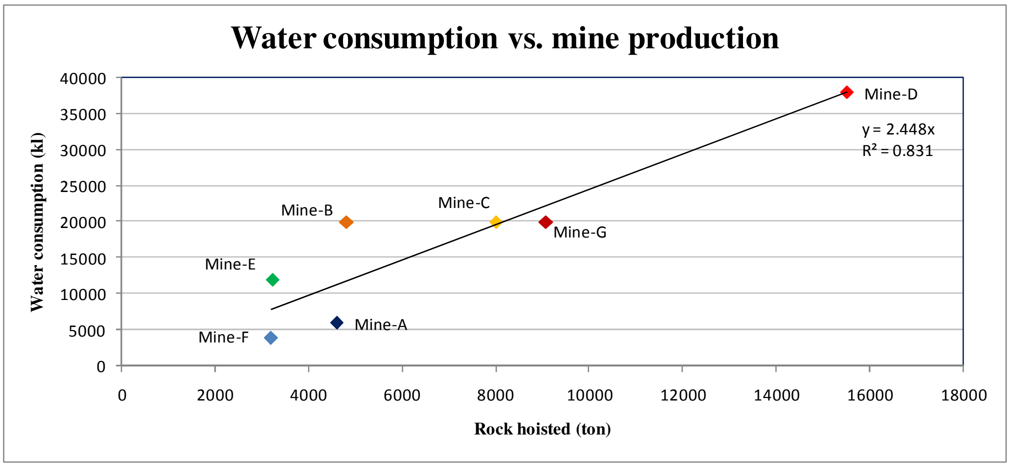


Figure 3-1: Water consumption vs. mine production (adapted from [32])

From Figure 3-1 it can be seen that Mine-B and Mine-E consume more water to mine a ton of rock than the average mine. It is therefore assumed that the water-savings potential at these mines will be more than at the others. Further investigations can be conducted on these mines to determine the water-reduction potential they offer.

The following three techniques have been identified to reduce the water consumption in deep-level mining:

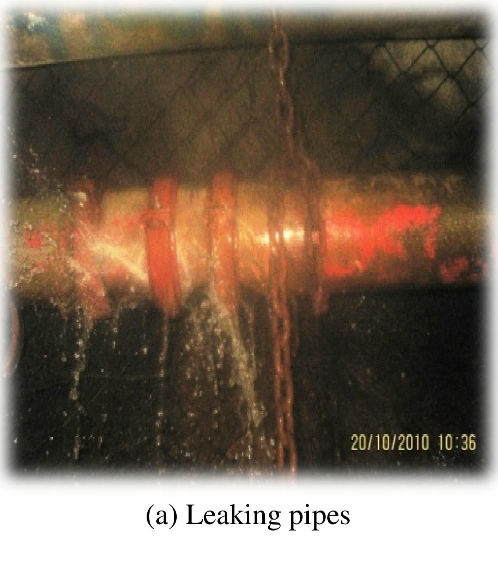
- Leak management
- Stope isolation control
- Water pressure control system

These techniques are discussed in the following sections.

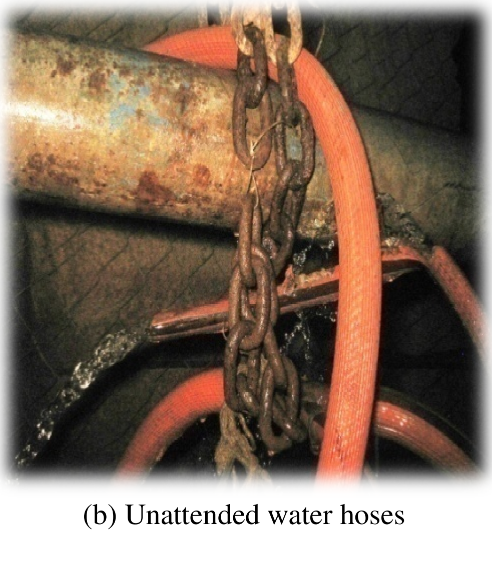
3.2.1 LEAK MANAGEMENT

The water reticulation system on a mine consists of many kilometres of pipe columns supplying water from the surface to the deepest and furthest mining and development areas. Leaking pipes are a common problem in the mining industry. This is due to the extremely rough conditions these pipes are exposed to.

Figure 3-2 shows leaks and water wastage commonly found in the underground mining industry. Many leaks are caused by faulty gaskets and ruptured piping. In some cases the valves of the water hoses are left open and the water is allowed to run freely.



(a) Leaking pipes



(b) Unattended water hoses

Figure 3-2: Examples of water wastage

Water pressure on mining levels is reduced by using PRVs and is reduced to a pressure typically in the region of 1000 kPa. At this pressure even a small hole in a pipe could lead to large volumes of water being wasted. This is demonstrated by Equation 3-1 which gives the flow rate of an incompressible fluid through a hole in a pipe.

The equation is derived using Bernoulli's theorem [52]. It is assumed that the chilled water used in the mining industry satisfies the criteria required to use the Bernoulli equation. A flow coefficient is included in the equation to account for the friction and other losses.

$$Q = \alpha \, A_t \sqrt{\frac{2(P_{inside} - P_{outside})}{\rho}}$$ [52] **Equation 3-1**

Where:

Q= Volumetric flow (m^3/s)
P_{inside}= Pressure inside the pipe (Pa)
$P_{outside}$= Pressure outside the pipe (Pa)
A_t = Area of the hole through which the flow occurs (m^2)
α = Flow coefficient, dimensionless
ρ = Fluid density (kg/m^3)

By using Equation 3-1 it can be calculated that a 10 mm hole, with a flow coefficient of 0.7 in a column at 1000 kPa could produce a flow rate of 2.4 l/s. This amounts to approximately 207 kl of wasted water per day. Using Equation 3-1 the relation between the fluid flow through a hole and the size of the hole at constant pressure is shown in Figure 3-3.

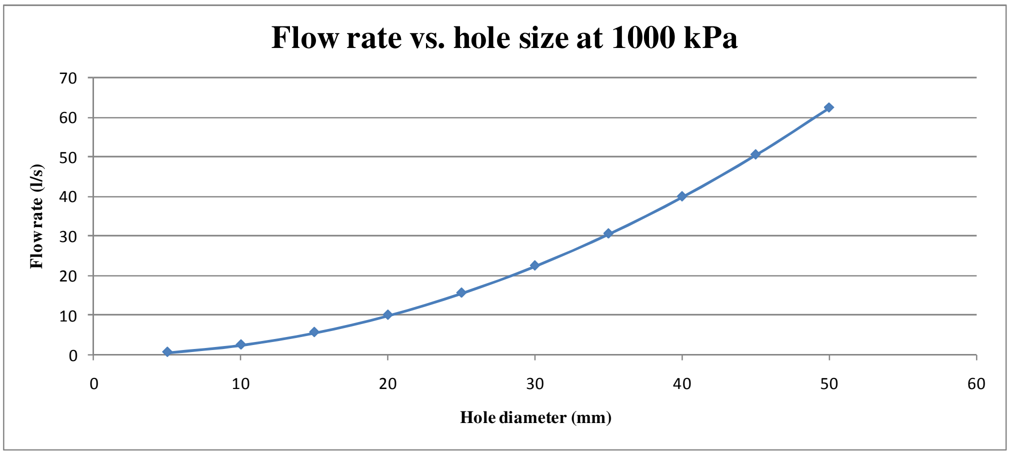


Figure 3-3: Relationship between flow rate and hole size

There are various techniques to identify leaks in fluid systems. Visual inspection of the column sections are by far the simplest and most cost-efficient method for detecting water leaks. There is a responsible person for each level and each section in the mining industry. It is this person's responsibility to ensure that the columns are in a good condition.

Because repairing water leaks is not the section foreman's highest priority, some leaks are left unattended for weeks. A dedicated team, whose priority it will be to identify safety hazards and wastage, should therefore be utilised. Identified leaks should be reported to the section foremen and mine managers.

To simplify the management and implementation of leakage repairs, a data-capturing unit can be utilised on which the identified leak can be stored. The leak type, size and location are required to simplify the repair process. With accurate data the leaks can be repaired quickly and effectively.

It is important to select an intrinsic safe device if it is going to be used in the underground mining environment. For water-leak management an ultra-rugged shock- and waterproof personal digital assistant (PDA), such as the Archer Field PC™ shown in Figure 3-4, can be used.

Figure 3-4: Archer Field PC™ for leak management

This PDA is preloaded with a Windows Mobile® operating system. This simplifies the development of a database software package used to capture the water leaks. The software database will be customised for each mine and will contain data entries such as:

- The shaft name on which the leak is identified.
- The level on which the leak is identified.
- The section within the level where the leak is situated.
- The type of leak, for example flange gasket, punctured column, broken valve, etc.
- The size of the hole.

An image of the identified leak will also be beneficial as it will assist in the description of the leak. The identified leak can be photographed using a rugged camera. The Pentax Optio W90 camera is a water-, dust- and shockproof camera and could therefore be used as part of the leak management tools. Figure 3-5 shows an image of the camera to be used for leak management.

Figure 3-5: Rugged waterproof camera for leak management [53]

A report will be generated containing all the information regarding the location and type of leak. The report will also contain a photograph of the leak. Additional information or comments regarding the leak can also be included in the report to simplify the repair of the leak. An example of such a report is included in Appendix A.

The report can be distributed weekly and feedback should be provided from the person responsible for the area. The water leak management and reporting system will simplify the maintenance of the water reticulation system. The system can be used to track the progress and cost savings of the identified leak repairs.

3.2.2 STOPE ISOLATION CONTROL

The stopes are the areas where the actual mining, drilling, blasting and scraping or sweeping of the reef takes place. The stope is accessed via the crosscut which is a branch of the main travel way. The water columns are usually situated along the travel ways and then taps off at each crosscut to supply the stope area with water.

As mentioned previously water is primarily used for cooling, drilling and sweeping purposes. Of these drilling and sweeping require human intervention. It would be good practice to isolate the water when no water-consuming mining activities are taking place. The mine activities can usually be categorised into three mining shifts, namely:

- Morning shift – drilling usually takes place. During the drilling shift holes are drilled into the rock face to certain depths for the explosives to be inserted.

- Afternoon shift – blasting usually takes place. The shaft is cleared to ensure that no miners are underground when the blasting takes place.
- Night shift – sweeping usually takes place. The rock is recovered from the stoping areas using water jets and scrapers.

Water in the stoping areas is required only during the drilling and sweeping shifts. No water is required in the stoping areas during the blasting shifts and therefore water supply can be terminated. The following two valve-control methods can be considered for stope isolation:

Manual stope isolation

Manual isolation valves will require the lowest initial capital expenditure. This is because only valves and no actuators, or any other control instrumentation, are required. The valve should be manually closed by the last miner to exit the stoping area and reopened by the first miner to enter the area.

Unfortunately this will depend on the miners' discipline to close the valve every time the shift team exits the stope area. It will be difficult to ensure that the miners close the valve when they exit the stopes. Manual operation of the valves is therefore not recommended as the miners' main priority is ore extraction and not water conservation.

Automatic stope isolation

Automatic control of the stope isolation valves will be the recommended option. Two techniques were considered to control the valves. The first technique makes use of timers which should be set according to the shift schedules. Figure 3-6 shows a test rig of the Floval stope-isolation system [54].

Figure 3-6: Example of a stope-isolation system [54]

The infrastructure required for the system to work is the valve, the timer unit and an electricity supply from the mine. The valve shown in Figure 3-6 makes use of the line fluid flow to actuate the diaphragm-type valve. Different valves and actuators can be used with the timer unit.

The only drawback of the timer unit is that each timer has to be manually set according to the mine shifts. There is however a manual override function which will allow a preset duration of additional water flow. The manual override is situated on the timer and therefore the miners have to exit the working area and walk to where the timer is located for the manual override.

The other option that can be used to trigger the valve operation is a centralised blasting system. Some mines use a centralised system to clear the shaft for blasting. A clearance key is issued to each section which should be inserted into the clearance box situated at the entrance of the crosscut to indicate that the section is clear for blasting.

The clearance box has an auxiliary contactor which can be used to trigger the valve solenoid. As the miners exit the section and no water is required the valve will close. As the miner enters the section after the blasting shift they have to remove the clearance key and the water supply is restored.

The advantage of this system is that it is not dependent on a fixed preset time schedule. The valve will only close when all the miners have exited the section. Each stope section has to be cleared before blasting may commence and therefore the miners are obligated to clear the section and thus isolate the water.

During shift changes and blasting shifts the water supply to the stopes can be terminated by closing the stope isolation valve. This will reduce water wastage from open-ended hoses, leaks and unclosed taps inside the stoping area.

With the stope-isolation system significant water consumption reduction can be accomplished. The mine should usually be cleared by approximately 18:00 for blasting after which the sweeping shift starts at approximately 22:00. If a flow rate of 2 l/s enters the stope area then a water reduction of more than 28 kl per day can be achieved for the four hours of the blasting shift.

3.2.3 PRESSURE SET-POINT CONTROL

Pressure control was implemented on some of the South African municipal water distribution networks with great success. Not only were the water leaks and wastage reduced, the frequency of system failures also reduced significantly [55].

From Equation 3-1 it is seen that the flow rate through a hole is determined by the size of the hole as well as the pressure of the fluid. A reduction in fluid pressure will result in a reduction in flow through the hole in the column, and therefore reduce the water wastage.

Tests were conducted by Vosloo [32] on a deep-level gold mine. At a typical mining level the pressure was reduced and the flow rate logged to determine the relation between the flow and pressure. The result of the test is shown in Figure 3-7.

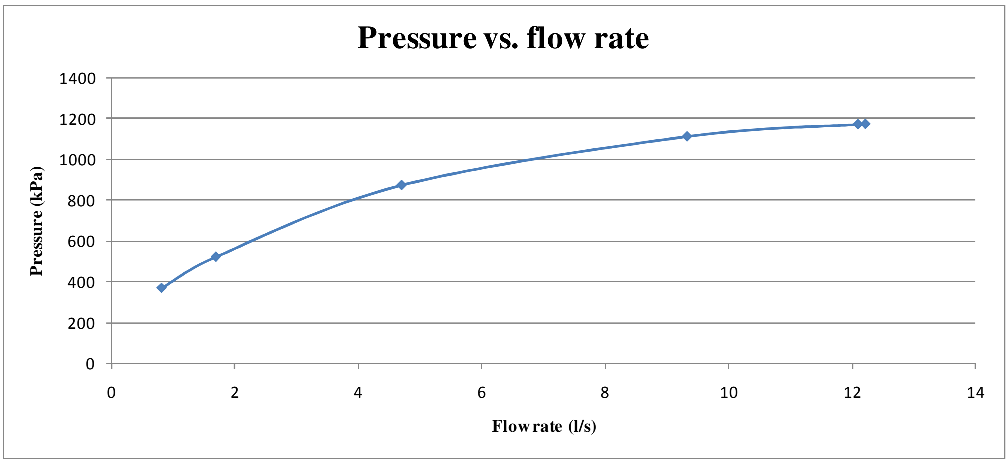


Figure 3-7: Relation between water pressure and flow on a mining level (adapted from [32])

From Figure 3-7 it can be seen that the water flow increases approximately exponential with an increased water pressure. The gradient and magnitude of the graph may vary from one level to another depending on the conditions of the downstream piping, and mining equipment installed (such as cooling cars).

The PRVs installed on the levels are set to maintain a downstream pressure that will only just allow sufficient flow during the peak drilling and sweeping shifts. The average water demand of a typical production level is shown in Figure 3-8.

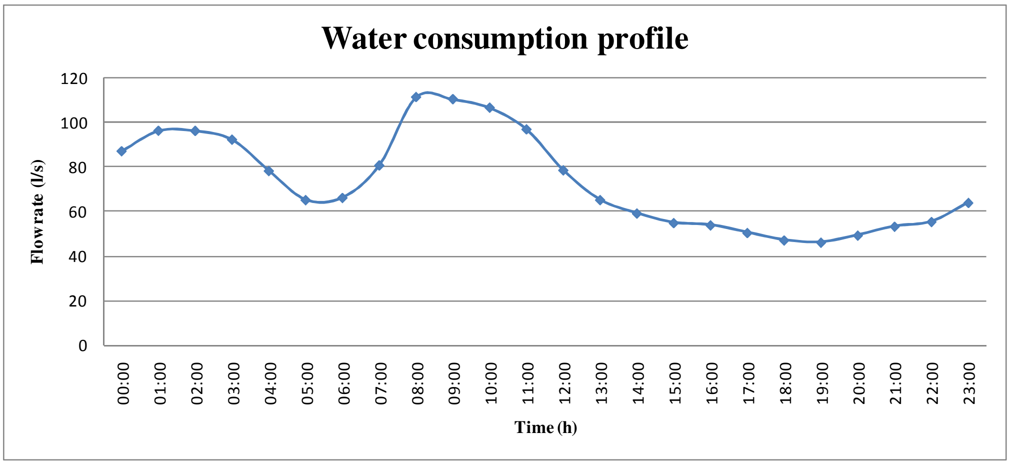


Figure 3-8: Typical water demand on a production level

The two visible peaks in Figure 3-8 indicate the sweeping and drilling shifts respectively. The demand decreases significantly after the two production shifts. If the pressure is controlled accordingly a further decrease in flow during the afternoon shift could be achieved.

During another test conducted by Vosloo [32], the downstream pressure of the production levels were reduced during the afternoon shift. The pressure reduction had a significant impact on the water supply flow rate, reducing the average flow by approximately 50 l/s for four hours. This is a total water reduction of approximately 720 kl. The result is shown in Figure 3-9, which contains the total flow rate and average pressure of the water supplied to the mine production levels.

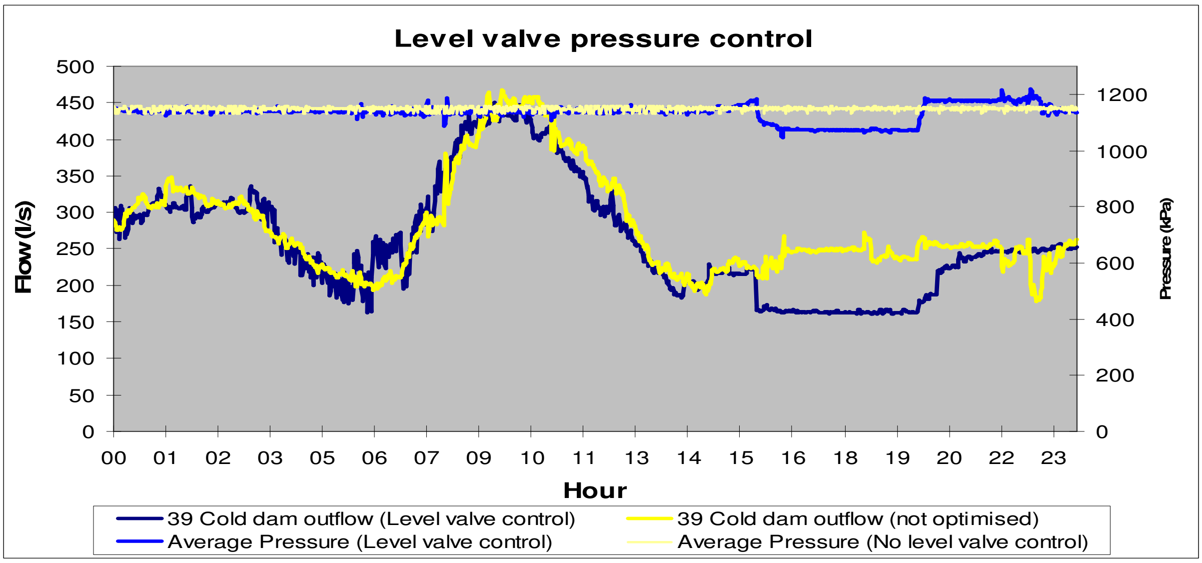


Figure 3-9: Result of pressure reduction test by Vosloo [32]

For pressure control a pressure schedule for each mining level will be predetermined according to the mine shift schedule and pressure requirements. The valves will be controlled to the specified downstream pressure using a PLC and feedback instrumentation. Each level will be controlled separately according to the level-specific requirements.

During the production shifts the water pressure will be controlled at a sufficient pressure value as not to negatively interfere with the mine's production capabilities. During the afternoon shift, where minimal water is required, the pressure can be reduced to a value that will allow only sufficient flow to the BACs, cooling cars, and to the working areas where water may be required.

Some water leaks occur on the column supplying water to all the stopes. Therefore the pressure control valves on each individual level will be installed as close to the main supply column as possible. This will reduce the water wastage on the entire level and not only in the stope areas, as is the case with stope isolation.

In some cases, if there are no BACs or other water consumers installed, the water supply to that level can be completely terminated during the blasting shift using the control valve. Care should be taken when completely terminating the water supply of a mining level not to cause water hammer. The valve should not be closed too quickly as this could have damaging effects and could result in production loss.

3.3 SIMPLIFIED METHODOLOGY FOR QUANTIFYING THE SAVINGS

In this section a simplified methodology to determine what the effect of a reduction in water volumes will have on the electrical energy consumed by the dewatering system is discussed. This is achieved by calculating the efficiency of the dewatering system and determining the quantity of water reduction. If the energy savings are known it can be used to determine the financial savings. The savings calculation methodology is discussed below.

3.3.1 DETERMINING THE DEWATERING SYSTEM EFFICIENCY

Calculations to determine the efficiency of an electrical pumping system can be complex. There is however a simplified method that could be used to approximate the pumping efficiency of the dewatering system as a whole. Equation 3-2 is used to compare the theoretical energy required to lift a mass of water to the actual electrical energy consumed by the pumps.

$$\gamma = \frac{E_{Theoretical}}{E_{Actual}}$$ **Equation 3-2**

Where,

$E_{Theoretical}$ = *Calculated energy required, excluding losses (kWh)*

E_{Actual} = *The actual electrical energy consumed (kWh)*

γ = *System efficiency (dimensionless)*

The theoretical energy required to lift a specific volume of water from the lowest storage dam to the surface can be calculated using Equation 3-3. The denominator (3.6 x 10^6) is used to obtain the answer in kW units. Friction losses are not included in this calculation.

$$P_{Theoretical} = \frac{Q\rho g h}{3.6 \times 10^6}$$ **Equation 3-3**

Where,

$P_{Theoretical}$ = *Calculated power required, excluding losses (kW)*

Q = *average flow rate (m^3/h)*

ρ = *the density of the liquid(kg/m^3)*

g = *gravitational acceleration (m/s^2)*

h = *pump height (m)*

The calculation for a typical gold mine is shown below for illustrative purposes.

If, for example the dewatering system of a 3000 m deep mine consumes an average of 300 MWh per day to pump a daily average of 25 Ml water to the surface, then the efficiency of the dewatering system can be calculated as follows:

$E_{Actual} = 300\ MWh$ (Actual electrical energy consumption)

$Q = 1041.67\ m^3/h$ (Average water flow rate, 25 Ml/24)

$\rho = 1000\ kg/m^3$ (Constant)

$g = 9.81\ m/s^2$ (Constant)

$h = 3000\ m$ (Mine depth)

$P_{Theoretic} = \frac{Q\rho g h}{3.6 \times 10^6}$

$P_{Theoretic} = 8.516\ MW$

$E_{Theoretic} = 204.38\ MWh$ ($P_{Theoretical}$ x 24)

The actual power consumption of the pumps was 300 MWh and therefore the efficiency of the dewatering system is:

$$\gamma = \frac{E_{Theoretical}}{E_{actual}}$$

$$\gamma \approx 0.68$$

Although the water is usually pumped using multiple cascaded pumping stations, the total potential power required to lift the water remains constant. The actual pumping power consumed will include all the losses. The friction losses are therefore seen as part of the system losses and the efficiency will be that of the system as a whole, and not only that of the dewatering pumps.

3.3.2 WATER REDUCTION VOLUMES

The calculated dewatering system efficiency can be used to estimate the effect that a reduction in water consumption will have on the dewatering system. The difficulty in estimating the savings that the water reduction will have on the system is to accurately determine the amount of water reduction that will be achieved.

Water reduction can be estimated by using an average 24-hour water consumption flow profile as shown in Figure 3-10. The water usage can then be divided between the three mining shifts and analysed to determine the cause of the water consumption. The amount of water being misused or wasted can be identified and the potential water reduction can be estimated accordingly.

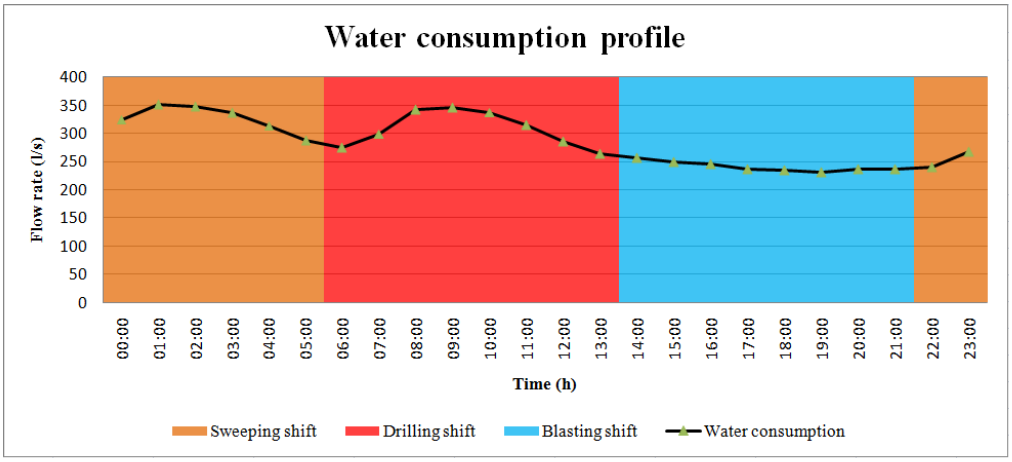


Figure 3-10: Water consumption profile

During the production shifts little or no water reduction potential can be expected. During nonproduction shifts the water consumption can be estimated according to the requirements of the equipment installed on the level. Some mines may allow for the water supply to a level to be completely terminated during the nonproduction periods. This will only be possible if there are no BACs or other equipment installed that requires a constant flow installed.

If, for example, the water flow required by installed equipment is 150 l/s during the afternoon shift, then the water reduction can be estimated by subtracting this requirement from the existing average during that specific time period. Therefore, if the average flow rate can be reduced to 150 l/s from 16:00 to 21:00 then the expected water consumption is shown in Figure 3-11. The total water reduction when subtracting the expected flow profile from the existing flow profile is 1.5 Ml.

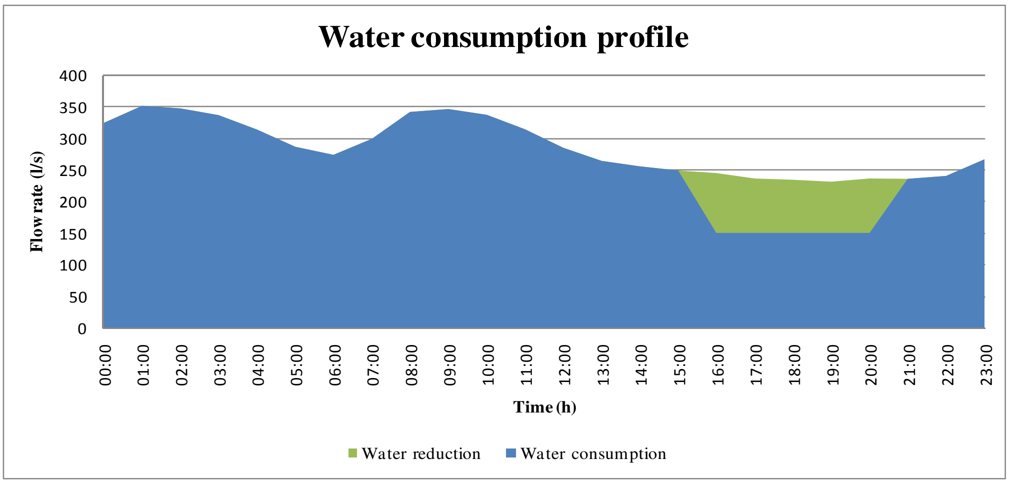


Figure 3-11: Reduced water consumption profile

The estimated water reduction can now be used to calculate the effect it will have on the dewatering system's energy consumption. This is done using Equation 3-2 and Equation 3-3 as discussed in the previous section.

The energy required to raise a total volume of 1.5 Ml water per day is calculated below:

$Q = 62.5\ m^3/h$ (Average water flow rate, 1.5 Ml/24)

$\rho = 1000\ kg/m^3$ (Constant)

$g = 9.81\ m/s^2$ (Constant)

$h = 3000\ m$ (Mine depth)

$\gamma = 0.68$ (Previously calculated)

$$P_{Theoretical} = \frac{Q\rho g h}{3.6\times10^6}$$

$P_{Theoretical} = 0.511\ MW$

$E_{Theoretialc} = 12.26\ MWh$ ($P_{Theoretical}$ x 24)

The estimated electrical energy required by the dewatering system based on the efficiency calculated previously can now be determined as shown below:

$$E_{Actual} = \frac{E_{Theoretical}}{\gamma}$$

$$E_{Actual} = 18.03 \text{ MWh}$$

Therefore the estimated electrical savings that can be achieved through pressure control is 18.03 MWh per day. This can be converted into a financial saving as discussed in the following section.

3.3.3 THE FINANCIAL SAVING CALCULATIONS

The mining industry normally incorporates the Eskom Megaflex tariff structure which is a time-of-use (TOU) tariff structure. The TOU tariff structure works on the principle that the consumer is charged for the power consumed at different rates according to the time period in which the power is consumed. The time periods can be divided into three categories, namely:

- Standard period
- Peak period
- Off-peak period

The rates differ according to the time of the day, the day of the week, as well as the season of the year and are based on the cost of generating electricity during each of these periods. This encourages the consumer to reduce power consumption during the peak demand periods. The reason for this is to reduce the power demand which places strain on the generating system during the peak demand periods. The 2009/2010 tariffs are shown in Table 3-1.

The effects of a reduction in water consumed will not be instantaneous as there is a delay before the water consumed by a level is pumped by the dewatering system. This is due to the time it takes the water to accumulate at the settlers, as well as the delay caused by the storage dams. The delay can be advantageous to the mine if the dewatering system storage dams are utilised optimally.

A reduction in water consumption will result in a proportional reduction in electrical power consumption. The storage capacities of the hot water storage dams can be utilised and managed to maximise the financial impact. This can be achieved by optimal pump selection and scheduling according to the TOU timetable.

Table 3-1: Eskom Megaflex TOU tariff table 2009/2010 (c/kWh) (adapted from [56])

	High demand season (June–August)			Low demand season (September–May)		
Time	**Weekday [c/kWh]**	**Saturday [c/kWh]**	**Sunday [c/kWh]**	**Weekday [c/kWh]**	**Saturday [c/kWh]**	**Sunday [c/kWh]**
00:00	19.29	19.29	19.29	13.79	13.79	13.79
01:00	19.29	19.29	19.29	13.79	13.79	13.79
02:00	19.29	19.29	19.29	13.79	13.79	13.79
03:00	19.29	19.29	19.29	13.79	13.79	13.79
04:00	19.29	19.29	19.29	13.79	13.79	13.79
05:00	19.29	19.29	19.29	13.79	13.79	13.79
06:00	36.05	19.29	19.29	19.72	13.79	13.79
07:00	138.58	36.05	19.29	32.19	19.72	13.79
08:00	138.58	36.05	19.29	32.19	19.72	13.79
09:00	138.58	36.05	19.29	32.19	19.72	13.79
10:00	36.05	36.05	19.29	19.72	19.72	13.79
11:00	36.05	36.05	19.29	19.72	19.72	13.79
12:00	36.05	19.29	19.29	19.72	13.79	13.79
13:00	36.05	19.29	19.29	19.72	13.79	13.79
14:00	36.05	19.29	19.29	19.72	13.79	13.79
15:00	36.05	19.29	19.29	19.72	13.79	13.79
16:00	36.05	19.29	19.29	19.72	13.79	13.79
17:00	36.05	19.29	19.29	19.72	13.79	13.79
18:00	138.58	36.05	19.29	32.19	19.72	13.79
19:00	138.58	36.05	19.29	32.19	19.72	13.79
20:00	36.05	19.29	19.29	19.72	13.79	13.79
21:00	36.05	19.29	19.29	19.72	13.79	13.79
22:00	19.29	19.29	19.29	13.79	13.79	13.79
23:00	19.29	19.29	19.29	13.79	13.79	13.79

Legend Off-peak | Standard | Peak

The total amount of dewatering pumps being operated during the standard and peak tariff periods can be limited to the number of pumps that will maintain safe dam levels but still ensure maximum load shift capabilities. The water balance can be restored during the off-peak rate period by utilising extra pumps during these periods.

The objective is to consume the greatest percentage of power during the off-peak period as the cost-per-unit power consumed is lowest. No power should be consumed during the peak periods as the cost-per-unit power consumed is highest during this period. The minimum power required to maintain safe dam levels should be used during the standard rates periods.

If however there are no load shift capabilities then the assumption is made that the total energy reduction achieved per day is averaged out over the 24-hour day. The financial savings can be determined by taking the actual 24-hour load profile and calculating the cost of the energy consumed during each hour according to the tariff. The weekday savings of a reduction of 18.03 MWh, if averaged out over 24-hours, are calculated below:

Table 3-2: Financial savings calculation

High demand season weekday tariffs					
Time	**Electricity unit cost [c/kWh]**		**Electricity reduction over hour [kWh]**		**Cost reduction [R]**
00:00	19.29		751.25		R145
01:00	19.29		751.25		R145
02:00	19.29		751.25		R145
03:00	19.29		751.25		R145
04:00	19.29		751.25		R145
05:00	19.29		751.25		R145
06:00	36.05		751.25		R271
07:00	138.58		751.25		R1 041
08:00	138.58		751.25		R1 041
09:00	138.58		751.25		R1 041
10:00	36.05		751.25		R271
11:00	36.05	**X**	751.25	**=**	R271
12:00	36.05		751.25		R271
13:00	36.05		751.25		R271
14:00	36.05		751.25		R271
15:00	36.05		751.25		R271
16:00	36.05		751.25		R271
17:00	36.05		751.25		R271
18:00	138.58		751.25		R1 041
19:00	138.58		751.25		R1 041
20:00	36.05		751.25		R271
21:00	36.05		751.25		R271
22:00	19.29		751.25		R145
23:00	19.29		751.25		R145
Total			**18 030**		**R9 344**

The estimated financial weekday saving that can be achieved in the high demand season by a daily reduction of 18.03 MWh is therefore R9 344 per day. Throughout the study the assumption is made that there are 22 weekdays per month. The weekend savings will not be included in the study.

3.4 WATER SUPPLY OPTIMISATION MANAGEMENT SYSTEM

To ensure sustainability and maximum savings from the optimised water reticulation system an automated system is required. HVAC International is an energy management company who developed a Real-time Energy Management System (REMS). The software has been implemented in various DSM projects in the mining industry.

The REMS for Water Supply Optimisation (WSO) platform has the capabilities required to implement the valve control discussed in the previous sections. The software can be used to communicate directly with PLCs or via the Object Linking and Embedding (OLE) for Process Control (OPC) to the mine's onsite SCADA system. The REMS-WSO software was the preferred choice for implementation and verification of the study on deep mines.

The REMS-WSO software consists of various component tools used on the mine water reticulation system. The platform, shown in Figure 3-12, will be used to construct a simplified layout representing the mine water reticulation system. The software tools used for pressure control, their functionality and input parameters are discussed below.

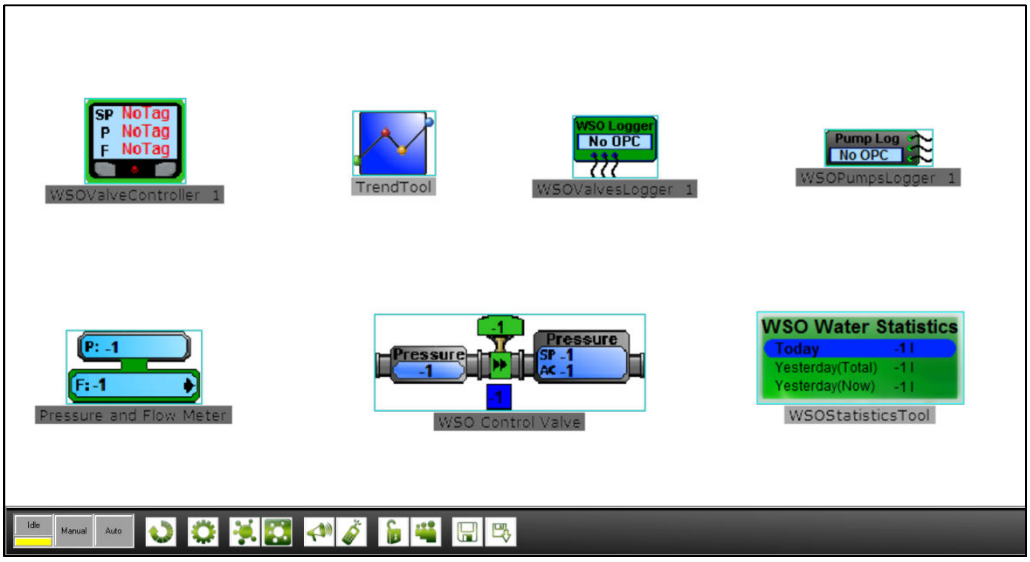


Figure 3-12: REMS-WSO software platform

The Control Valve icon shown in Figure 3-13 represents the control valve installed for pressure control. The pressure upstream and downstream of the valve, as well as the flow through the valve, can be displayed on the Valve component. Feedback on the current valve status and position is also displayed on the Valve icon.

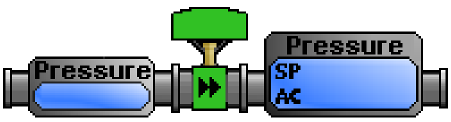


Figure 3-13: REMS-WSO Valve icon

The flow (F) and pressure (P) of each level that is not equipped with a control valve can be displayed using the Pressure and Flow Meter icon shown in Figure 3-14. It is important to display the volume of water consumed on each level as well as the pressure at which the water is supplied. The control room operators can monitor these statuses to identify irregularities.

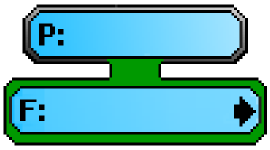


Figure 3-14: REMS-WSO Pressure and Flow Meter icon

The Valve Controller icon shown in Figure 3-15 is used to supply the valve with a desired pressure set-point. A 24-hour pressure profile for each day will be preprogrammed in the Valve Controller component. The Valve Controller will write the set-point to the valve according to the time of day.

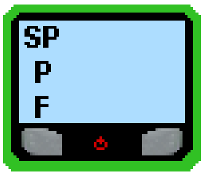


Figure 3-15: REMS-WSO Valve Controller icon

The desired set-point (SP) as well as the actual pressure (P) and flow (F) are displayed on the Valve Controller. The controller will be used to specify a pressure set-point profile for normal weekdays, working Saturdays, and nonworking Saturdays and Sundays. The controller will be programmed with the planned working-day schedule three months in advance.

The software platform contains a component capable of logging the valve input set-point and the valve feedback parameters. The feedback includes the pressure upstream and downstream of the valve, the flow through the valve, and the valve position. The data logged will be used to report on the valve control. The Valve Logger icon is shown in Figure 3-16.

Figure 3-16: REMS-WSO Valve Logger icon

Using the Trending tool the flow, pressure, and pressure schedules can be graphically displayed on the screen. The data is stored in two-minute increments and accessible by the Trend tool if historical trends should be viewed. The Trend tool icon is shown in Figure 3-17.

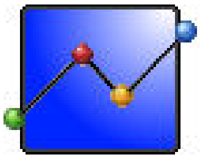


Figure 3-17: REMS-WSO Trend tool icon

Another useful component included in the software is the Statistics tool icon shown in Figure 3-18. This component will be used to calculate and display the total water consumption. The consumption of each level as well as the total mine water consumption can be displayed on the computer screen.

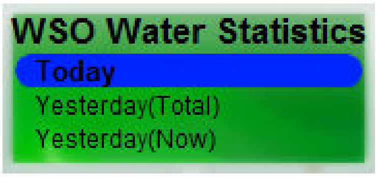


Figure 3-18: REMS-WSO Water Statistics tool icon

The Pump Logger icon is shown in Figure 3-19. This component will be used to log the instantaneous electricity consumption of the dewatering pumps. This data will be used to determine the total daily electricity consumption of the dewatering system.

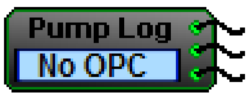


Figure 3-19: REMS-WSO Pump Data Logger icon

The REMS-WSO software will be installed on stand-alone servers which will have full control of the valves installed on the water supply system. A daily impact report will be generated and sent to the relevant mine representatives as part of the sustainability measures.

Although these tools provide a good platform for control, it is crucial to design and implement the correct control philosophy. An incorrect control philosophy can be damaging to the infrastructure and could negatively influence the production capabilities of the mine.

3.5 SUMMARY

Three techniques were discussed which will result in a reduction in water consumption in the mining industry. The techniques include water leak management, stope isolation systems, and water supply pressure control.

A significant water consumption reduction can also be achieved by identifying and repairing water leaks. The pressure of the supply water can be controlled by means of control valves. There are various types of control valves that can be used depending on the application. The correct control valve and trim must be selected to avoid damage to the valve and pipe network.

A reduction in water consumed by the mine will result in a reduction in electrical energy required to extract the water from the mine. The expected electrical energy savings can be calculated using simple equations. The electrical tariff structure should be considered when developing a pump scheduling in order to obtain maximum financial savings.

Implementation of automated systems is preferred to avoid human error and other discipline-related issues. The REMS-WSO software platform can be used to automatically control valves according to predefined pressure set-points. The information regarding the statuses of valves and water flow can be displayed onscreen.

In the next chapter the design and implementation of these strategies on deep mines with the issues encountered will be discussed in detail.

CHAPTER 4 : IMPLEMENTATION AND RESULTS

4.1 PREAMBLE

This chapter describes the application and testing phase of the techniques discussed in Chapter 3. The pressure control technique was initially tested at AngloGold Ashanti's Kopanang gold mine as discussed in Case Study 1. After successful testing the findings were applied in Case Study 2 and expanded to identify the potential savings on other gold mines.

4.2 CASE STUDY 1

4.2.1 INTRODUCTION

Figure 4-1: Kopanang gold mine

Kopanang gold mine forms part of the AngloGold Ashanti group and is situated near Orkney on the Free State side of the Vaal River accessing the Vaal Reef. The mine comprises a single-shaft system mining at depths between 1 350 m and 2 240 m below the surface. Kopanang is a Sotho name meaning 'place where people come together'.

4.2.2 OVERVIEW OF MINE WATER RETICULATION

The mine utilises only surface refrigeration plants to cool the water. This water is stored in the surface cold water storage dam. From the surface storage dam water is gravity-fed through a single column to the underground storage dam situated on 39 Level. From the 39 Level storage dam the water is gravity-fed down the single main supply column to the mining levels. Figure 4-2 shows a simplified water reticulation of the mine.

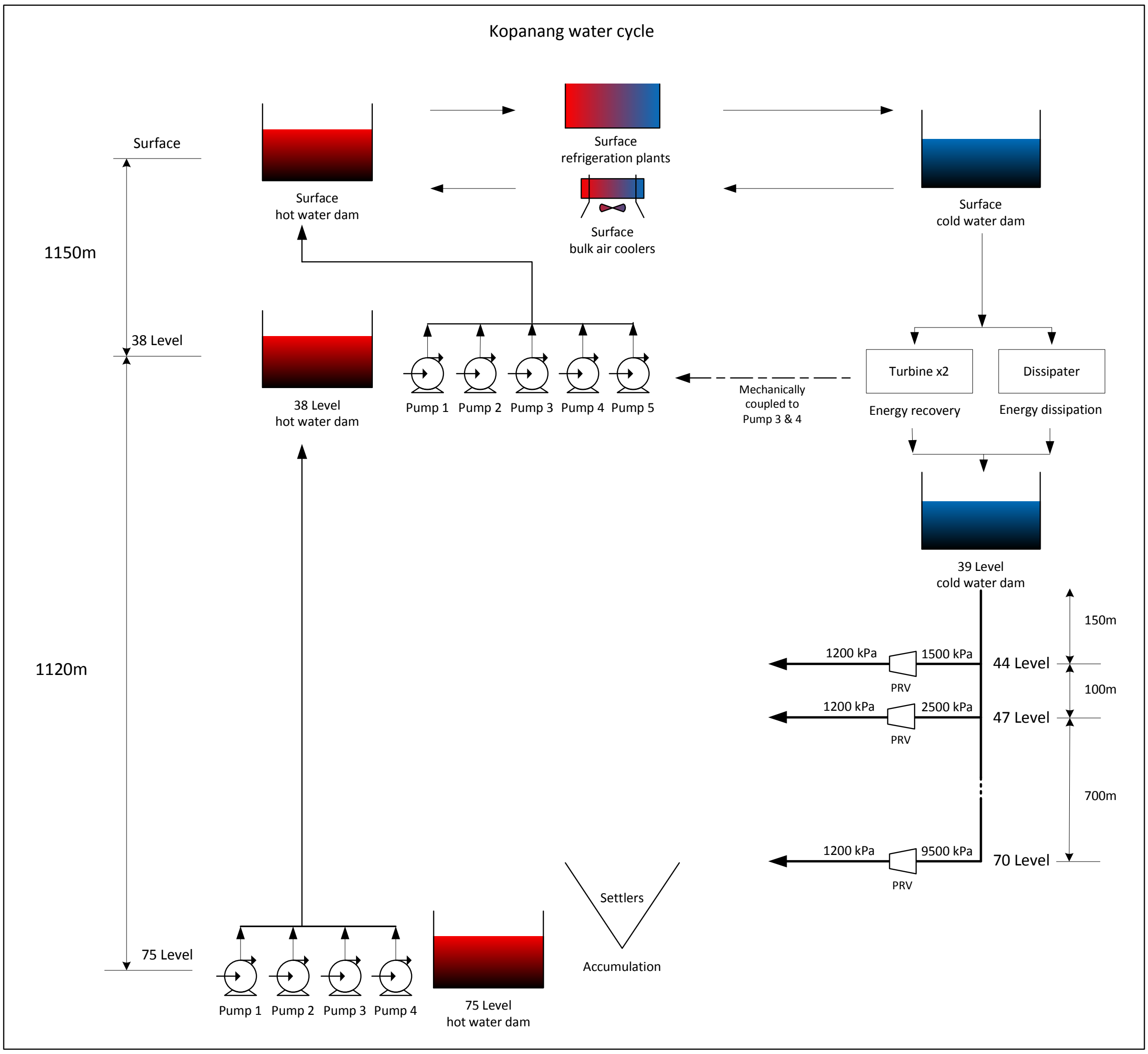


Figure 4-2: Simplified water cycle of Kopanang gold mine

Each level is supplied with water from a single supply column which feeds off the 39 Level cold storage dam. The water pressure on each level is reduced by a pressure-reducing station which consists of automated globe-type control valves. The downstream pressure is controlled at a set-point pressure which can be changed using the mine's SCADA system.

The used water from the mining levels accumulates at the settlers on 74 Level and is pumped from 75 Level's hot water storage dam, 2 286m below surface. The dewatering system of the mine consists of two cascading pump stations situated on 75 Level and 38 Level respectively. The installed capacities of the dewatering pumps are shown in Table 4-1.The mine also utilises two turbines which are mechanically coupled to multistage centrifugal pumps: Pump 3 and Pump 4 on 38 Level pump station.

Table 4-1: Kopanang installed pump capacities

Station	Pump no	Installed capacity (kW)	Rated flow (l/s)
38 Level	Pump 1	2 000	115
	Pump 2	2 000	115
	Pump 3	0 (Turbine)	115
	Pump 4	0 (Turbine)	115
	Pump 5	2 000	115
75 Level	Pump 1	2 000	115
	Pump 2	2 000	115
	Pump 3	2 000	115
	Pump 4	2 000	115

These turbines act as an energy recovery system as it utilises the energy contained in the supply water to drive the dewatering pumps. A flow of approximately 205 l/s chilled water through the turbine results in an average of 115 l/s pumped to surface by the pump connected to the turbine.

4.2.3 WATER AND POWER DEMAND

The mining levels consume on average 20 Ml water per day from the 39 Level storage dam. The water consumption profile for a typical mine production day is shown in Figure 4-3. From this figure the three mining shifts, and their respective water demands, can be identified. The maximum water demand takes place during the drilling shift from 06:00 to 12:00 and during the sweeping swift from 22:00 to 04:00.

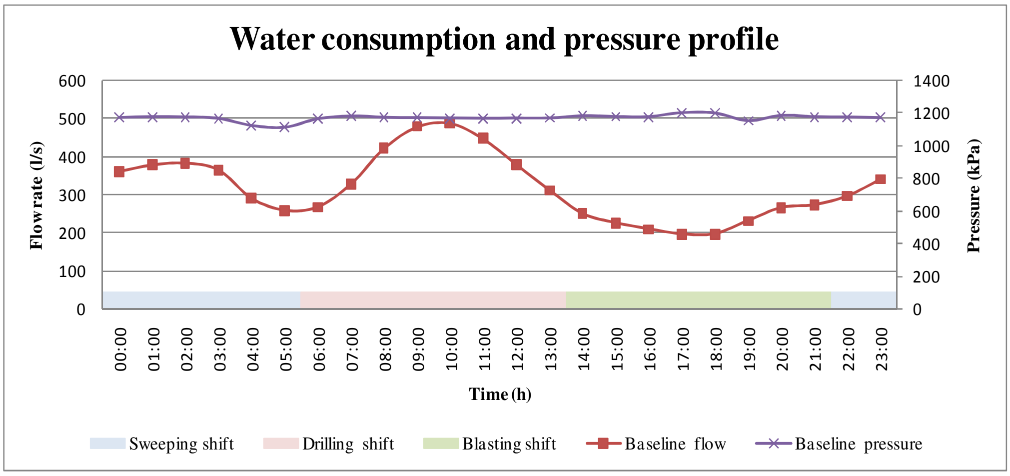


Figure 4-3: Production levels water consumption profile for Kopanang

Unlike most mines this mine has a loss of approximately 1 Ml water per day. There is uncertainty as to what the reason for the loss of water is, and where the water flows to. The mine has to replace the lost water and does so by purchasing clean water from Rand Water. The dewatering system pumps on average 19 Ml water from the shaft to surface consuming approximately 130 MWh per day.

Using Equation 3-2 and Equation 3-3 the efficiency of the dewatering system can be calculated. These calculations are shown below using actual measured data obtained from the mine.

$E_{Actual} = 130\ MWh$ (Actual measured)

$Q = 791.67\ m^3/h$ (Average flow rate, 19 Ml/24)

$\rho = 1000\ kg/m^3$ (Constant)

$g = 9.81\ m/s^2$ (Constant)

$h = 2286\ m$ (Height from 75 Level to surface)

$$P_{Theoretical} = \frac{Q\rho g h}{3.6\times10^6}$$

$$P_{Theoretical} = 4.93\ MW$$

$E_{Theoretical} = 118.36\ MWh$ ($P_{Theoretical}$ x24)

$$\gamma = \frac{E_{Theoretical}}{E_{Actual}}$$

$$\gamma \approx 0.91$$

This is relatively high for a mine-dewatering system and can be attributed to the utilisation of the two turbine driven pumps on 38 Level.

The mine has successfully implemented a DSM project on their dewatering system which shifts almost the entire load from the Eskom peak demand periods. The present electrical power demand profile of the dewatering system is shown in Figure 4-4.

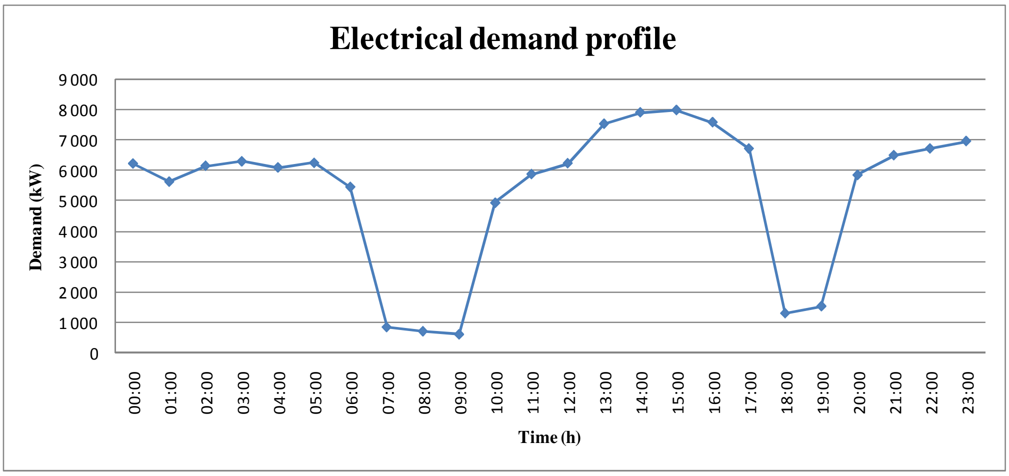


Figure 4-4: Electrical demand of the dewatering system for Kopanang

4.2.4 DEMAND OPTIMISATION STRATEGY AND EQUIPMENT SELECTION

The mine has already incorporated pneumatically actuated globe-control valves on all the water consuming levels. The mine utilises these valves to reduce the supply water pressure. All the levels are equipped with the PLCs, flow meters and pressure transmitters required to control the valves at the desired pressure. Therefore no additional equipment installation is required to perform pressure set-point control.

The effect of the pressure set-point control strategy is tested on the mine by changing the downstream pressure of the control valves. This is accomplished by changing the pressure to which the valve is controlled using the mine's SCADA system. The mine allows only partial closing of the valves as some levels require continuous flow.

During the drilling and sweeping shifts no adjustment were made to the pressure. However from 16:30 to 21:00 during the blasting shift, the average pressure is reduced from 1200 kPa to 700 kPa. After 21:00 the pressure is restored to the normal operating pressure of 1200 kPa. The result obtained from this test is discussed in the next section.

4.2.5 RESULTS OF OPTIMISED WATER DEMAND

The result of the test carried out at Kopanang gold mine is shown in Figure 4-5.The average flow of the water from the 39 Level dam is plotted together with the average water supply pressure on the production levels. This figure shows that the flow decreases significantly with the reduction in supply pressure. When a level does not require water the valve can be closed off completely increasing the savings.

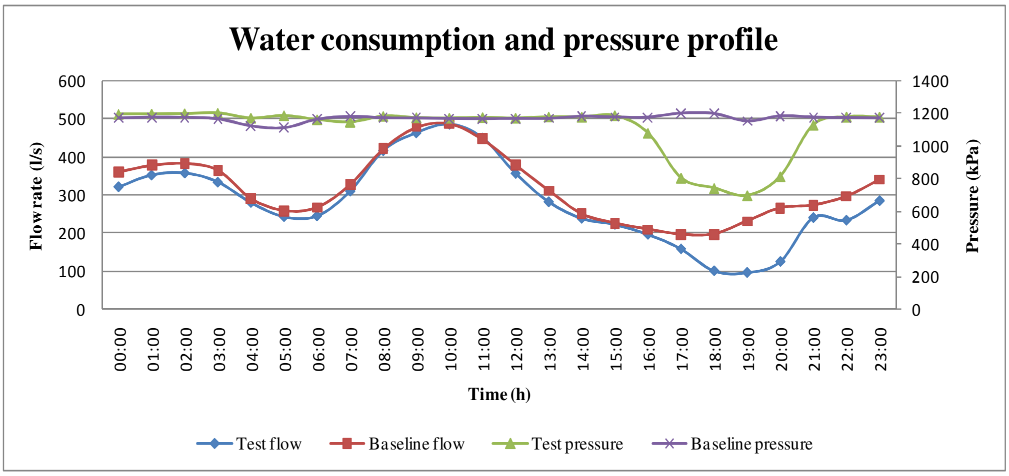


Figure 4-5: Results of the water pressure control at Kopanang

During the test a combined total water consumption reduction of approximately 1.4 Ml was achieved. By taking the efficiency of the dewatering system into account, the reduction in water consumed will result in an average daily electrical energy reduction of 9.6 MWh. This calculation is shown below:

$Q = 58.33\ m^3/h$ (Average flow, 1.4 Ml/24)

$\rho = 1000\ kg/m^3$ (Constant)

$g = 9.81\ m/s^2$ (Constant)

$h = 2286\ m$ (Height from 75 Level to surface)

$\gamma \approx 0.91$ (Previously calculated)

$$P_{Theoretical} = \frac{Q\rho gh}{3.6\times10^6}$$

$$P_{Theoretical} = 363.38\ kW$$

$$E_{Theoretical} = 8.721\ MWh$$ ($P_{Theoretical}$ x 24)

$$E_{Actual} = \frac{E_{Theoretical}}{\gamma}$$

$$E_{Expected} \approx 9.6\ MWh$$

Because of the delay in the water cycle, the water sent underground is not pumped out instantaneously. The test was carried out over a period of one day only, and consequently the effect that the reduction in water consumed had on the electrical consumption is not available instantaneously. Therefore, the expected electrical demand profile is constructed by subtracting the calculated energy savings from the actual measured data.

The electrical demand reduction will take place during the standard and off-peak periods because normally no pumps are operated during the Eskom peak period due to the load-shifting initiative. The expected electrical demand profile is shown in Figure 4-6.

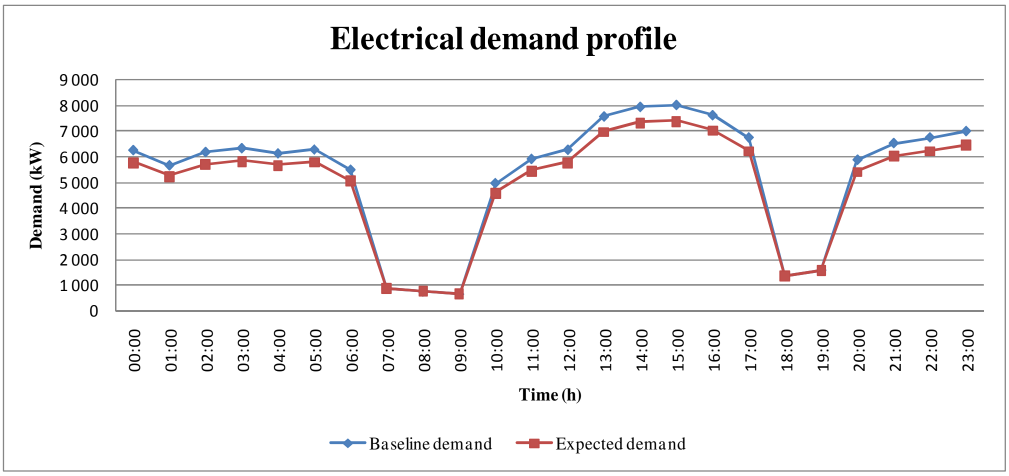


Figure 4-6: Electrical impact of the water pressure control at Kopanang

The financial impact of the water reduction is calculated using the average off-peak and standard electricity cost rates. This is because no electrical power is consumed during the peak period. The financial impact of the reduction in electrical energy consumption is R1 662 per day during the low demand season and R2 798 per day during the high demand season. This will result in an annual saving of approximately R513 700 based on 22 workdays per month.

4.3 CASE STUDY 2

4.3.1 INTRODUCTION

Figure 4-7: Kusasalethu mine

Kusasalethu, formerly known as Elandsrand, forms part of the Harmony group. The mine is situated on the border of the Gauteng and North West provinces near Carletonville, accessing the Ventersdorp Contact Reef. Kusasalethu comprises twin vertical and twin subvertical shafts reaching a depth of 3.6 km below the surface. The mine has extended its mine life to 2037, hence the name change to 'Kusasalethu' a Zulu word meaning 'our future' [57].

4.3.2 OVERVIEW OF MINE WATER RETICULATION

Kusasalethu utilises both surface and underground refrigeration plants in order to adequately cool the mine. Chilled water is gravity-fed to the various cascading storage dams on 29 Level, 52 Level, 71 Level and 95 Level through a single supply column. The mine has an intricate water supply network as shown in Figure 4-8.

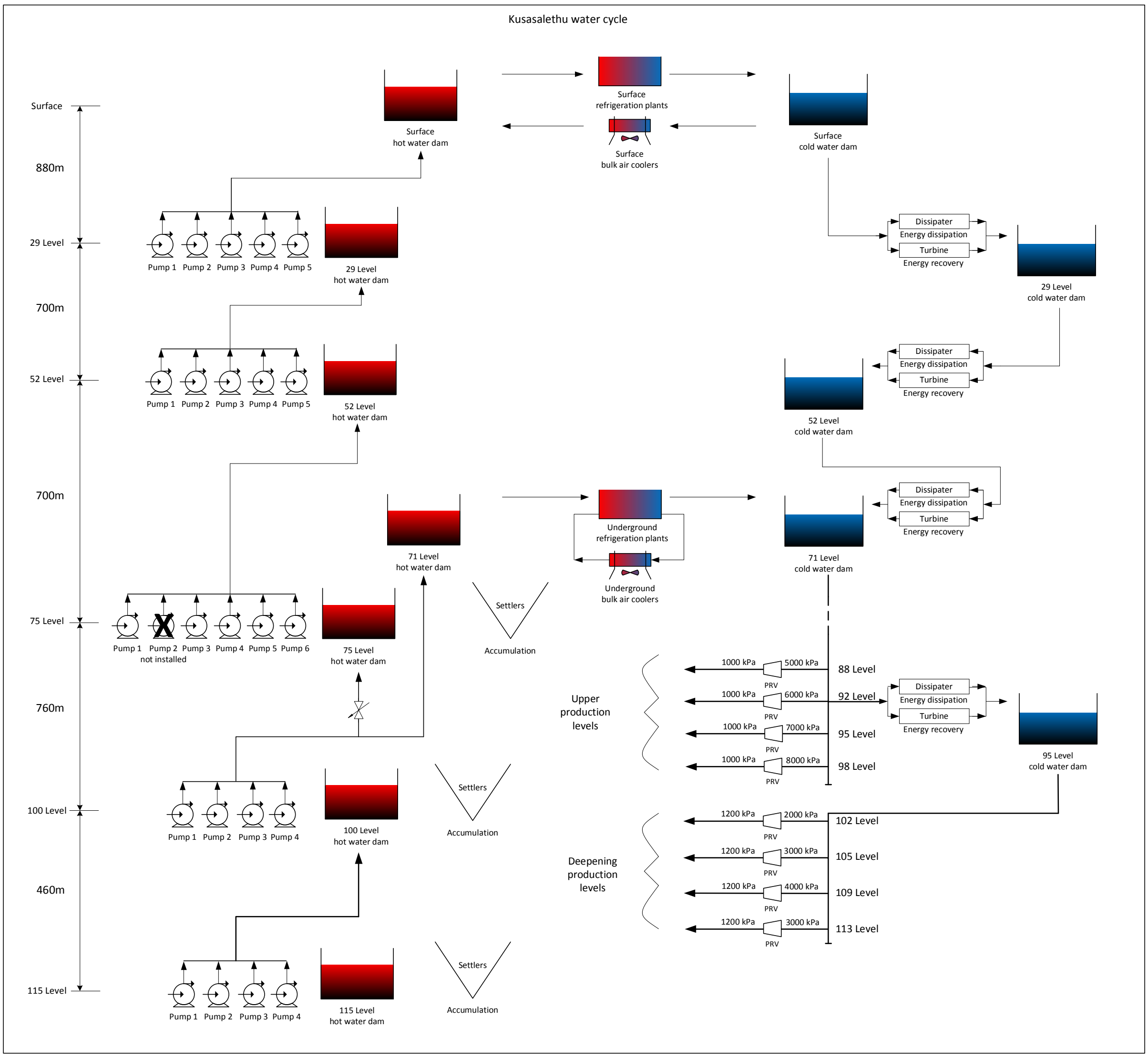


Figure 4-8: Kusasalethu water cycle overview

The refrigeration system consists of four refrigeration units on the surface and six underground units situated on 71 Level. The total installed capacity of the refrigeration system is 17.8 MW with an average energy consumption of 240 MWh per day.

Two of the underground refrigeration plants are used to cool down and circulate the water through the underground BAC situated on 73 Level. The remaining four refrigeration units are used to cool the water from 71 Level hot dam and add it to 71 Level cold water storage dam.

The mine has four turbine generators installed on the water supply network which are situated on 29 Level, 52 Level, 71 Level and 92 Level respectively. During the period of the study only the turbine on 29 Level was functional. Although it is still in the commissioning phase it has an average generating capacity of 1.6 MW. The electricity generated by the turbine is fed into the mine's electricity distribution network. This reduces the total electricity consumed from the electricity supplier.

The dewatering system consists of five cascading pump stations and storage dams situated on 115 Level, 100 Level, 75 Level, 52 Level, and 29 Level respectively. Water used on 98 Level and higher accumulate at the settlers on 98 Level and is pumped from the 100 Level pump station. Water used below 98 Level accumulates at 113 Level settlers and is pumped from 115 Level pump station.

The hot water storage dam on 71 Level is kept as full as possible at all times. This is to ensure that the minimum water quantity is pumped to the surface. The control philosophy of the dewatering system will not be altered during the implementation of the study. The installed capacities of the dewatering pump stations are shown in Table 4-2.

Table 4-2: Kusasalethu installed pump capacities

	29 Level		52 Level		75 Level		100 Level		115 Level	
Pump No	Installed capacity (kW)	Rated flow (l/s)	Installed capacity (kW)	Rated flow (l/s)	Installed capacity (kW)	Rated flow (l/s)	Installed capacity (kW)	Rated flow (l/s)	Installed capacity (kW)	Rated flow (l/s)
Pump 1	1 200	150	1 200	150	1 275	150	1 600	240	2 500	265
Pump 2	1 200	150	1 200	150	1 275	150	-	-	2 500	265
Pump 3	1 200	150	1 200	150	1 115	150	1 400	240	2 500	265
Pump 4	1 200	150	1 200	150	1 100	150	1 600	240	2 500	265
Pump 5	1 200	150	1 200	150	1 115	150	1 600	240	-	-
Pump 6	-	-	-	-	1 115	150	-	-	-	-

Water pressure is reduced on each level by a PRV which is manually configured to provide a fixed downstream pressure. The average pressure downstream of the PRV is 1 000 kPa on all levels up to 98 Level. Although there is communication to each level via a PLC or a Remote Input and Output device (RIO), automated pressure control cannot be applied to this installed PRV type.

There are two BACs installed on each of the Deepening mine levels (new production levels as shown in Figure 4-8), one on the west side and the other on the east. These BACs will be supplied with chilled water from the 95 Level chilled water storage dam using high pressure columns with water pressure estimated to be increased to 3 000 kPa. This will allow the mine to use the pressure of the supply water to force the water through the BAC and up to 98 Level. The water will then be pumped from the 100 Level pump station which is approximately 3 000 m below surface.

The stopes and working areas on the Deepening mine will be supplied with water at a lower pressure downstream of the BAC. The Deepening mine levels are not equipped with the necessary instrumentation to monitor and manage the water usage of these levels. This makes it difficult to determine exactly how much water is consumed on these levels and by which process.

4.3.3 WATER AND POWER DEMAND

The water consumption of the mine and the electrical power consumption of the dewatering system were logged during a three-month baseline period namely August, September and October 2009. This data was verified by an independent measuring and verification team and is used as a baseline for this study [58]. The post-implementation performance of the study will be measured and compared to this baseline. The data was obtained and logged from the mine's SCADA system.

This mine consumes an average of 24 Ml water from the surface cold water storage dam per day. The 24-hour water consumption profile data is included in Appendix B. The total water consumption is divided into two categories namely the 88–98 Level flow and the Deepening mine flow. The total water consumption flow profile, which is the combination of the 88–98 level and the Deepening level flows, is shown in Figure 4-9.

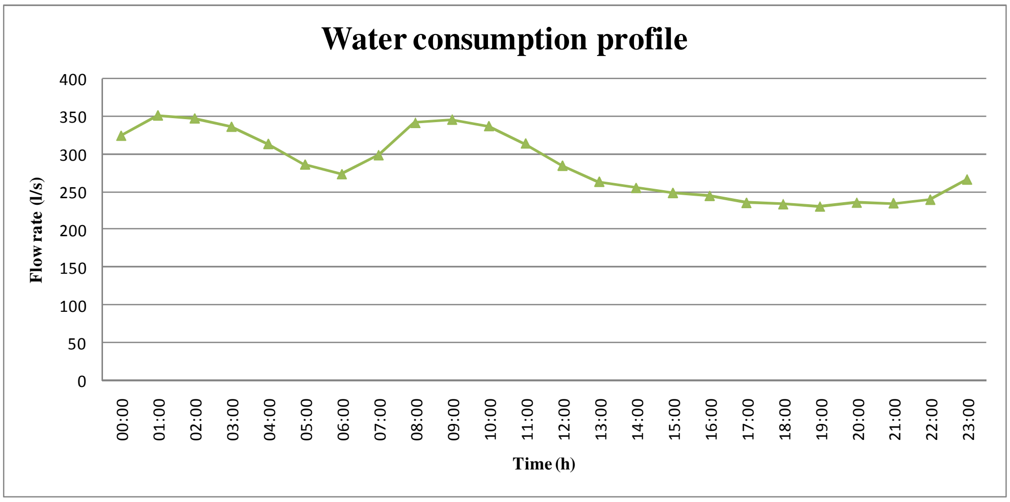


Figure 4-9: Kusasalethu combined production levels water consumption baseline flow

The dewatering system of the mine pumped an average of 26 Ml water to surface per day. The difference in water consumed and the water extracted (2 Ml) by the mine can be ascribed to fissure water. Using the baseline data the dewatering system from 100 Level upwards is calculated to consume an average of 281 MWh per day. The electrical power consumption data for 115 Level pump station was not available during the baseline period and it is therefore not included in the calculations. Figure 4-10 shows the electrical power demand of the dewatering system.

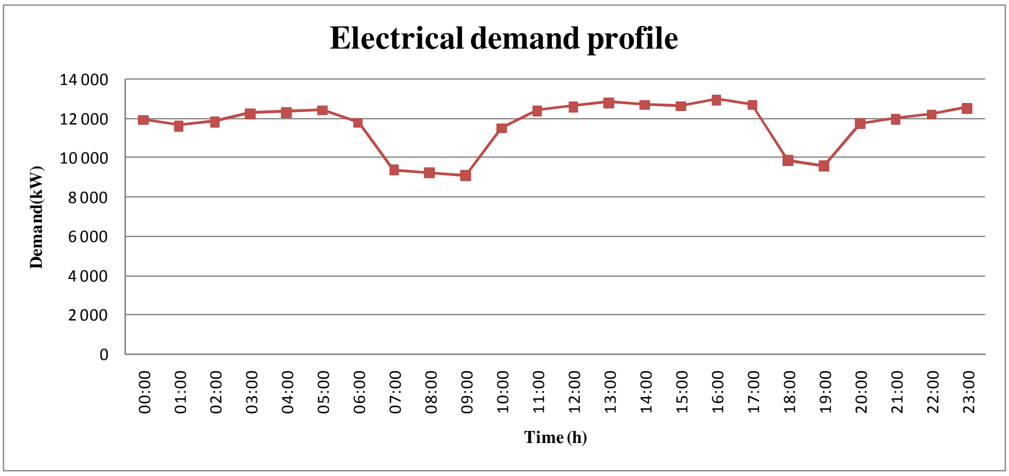


Figure 4-10: Electrical demand of the dewatering system for Kusasalethu (adapted from [58])

According to the production figures obtained from the mine, an average of 2 658 ton of combined reef and waste was mined per day during the baseline period. This relates to an average water consumption of approximately 8.95 kl to mine a ton of rock.

The energy required to raise the water from 100 Level to surface, excluding all system losses, is calculated using Equation 3-3.These calculations are shown below.

$E_{Actual} = 281\ MWh$ (Actual measured baseline consumption)

$Q = 1083\ m^3/h$ (Average flow rate, 26 Ml/24)

$\rho = 1000\ kg/m^3$ (Constant)

$g = 9.81\ m/s^2$ (Constant)

$h = 3000\ m$ (Height from 100 Level to surface)

$$P_{Theoretical} = \frac{Q\rho gh}{3.6\times10^6}$$

$$P_{Theoretical} = 8.85\ MW$$

$$E_{Theoretical} \approx 212\ MWh$$ ($P_{Theoretical}$ x 24)

The efficiency of the dewatering system is therefore:

$$\gamma = \frac{E_{Theoretica)}}{E_{actual}}$$

$$\gamma \approx 0.75$$

The efficiency of the dewatering system will be used to estimate the effect that a reduction in water consumed will have on the electrical energy consumption.

4.3.4 DEMAND OPTIMISATION STRATEGY AND EQUIPMENT SELECTION

Case Study 2 will entail the evaluation of all three the techniques discussed in Chapter 3 to reduce the electricity consumption of the dewatering system. The equipment necessary to implement pressure set-point control and automated stope isolation on the mine, as well as a leak-management tools will be supplied and installed. Where possible the equipment already installed will be utilised to reduce the implementation cost of the study.

For leak management the mine assigned two of their staff members to identify and report on water leaks. PDAs and cameras were implemented as part of the leak management strategy of this study. The data captured on the PDA together with a photo of the leak is used to generate a leak report. The report is sent to the person responsible for the section in which the leak is located. Regular feedback is then requested regarding the repair status of the leaks.

As part of this study a total of 30 stope isolation valves were installed at the working stopes on the main production levels. The mine has installed a centralised blasting system clearance box at the entrance of each crosscut on the production levels. An auxiliary contact on the centralised blasting system is used to control the stope isolation valve. As the shift leader of each section clears that section the valve closes terminating the water supply to that section.

Butterfly valves were selected as they are suited for on/off applications and take up little space. The crosscut columns have a diameter of 150 mm. A 150 mm butterfly valve was selected to avoid excessive friction losses over the stope valve when the valve is in the open position. A 350 kPa pneumatic actuator is used to actuate the valve. To avoid influencing production in the event of a power failure, the valve is set to a fail-open position. The stope isolation valve and actuator assembly is shown in Figure 4-11.

The mine installed 250 mm pneumatically actuated butterfly valves on the upper production levels downstream of the PRV. A 100 mm bypass section was later installed over the butterfly valve to prevent damage to the column and PRV during valve shutoff. The butterfly valve was closed during nonproduction shifts; but with little effect as all the water was forced through the 100 mm bypass section.

Figure 4-11: Stope isolation valve

As part of this study globe-type control valves were installed to enable pressure set-point control on the upper production levels. Due to financial constraints and the high cost of the valves a decision was made to use a smaller globe valve and to install it on the 100 mm bypass. A schematic of the valve and bypass section installed on each of the upper production levels is shown in Figure 4-12. The specifications of the control valves are included in Appendix C.

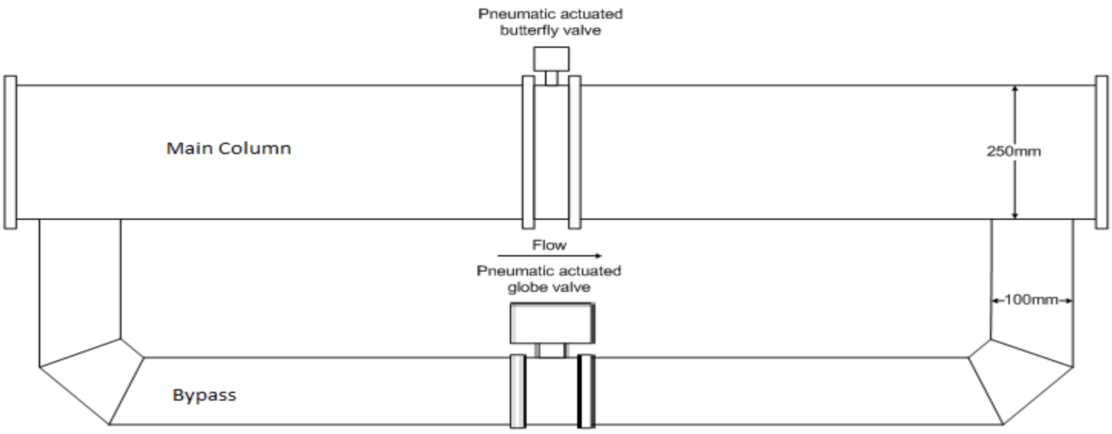


Figure 4-12: Bypass control valve assembly

Due to the high-pressure columns utilised on the Deepening mine no control valves were installed on these levels. On each of these columns a pressure transmitter and a nonintrusive ultrasonic flow meter were also installed. This was to enable water consumption monitoring of each individual level.

A simplified layout of the water supply network is shown in Figure 4-13. The equipment already installed, as well as the planned installations for this study is included in this schematic.

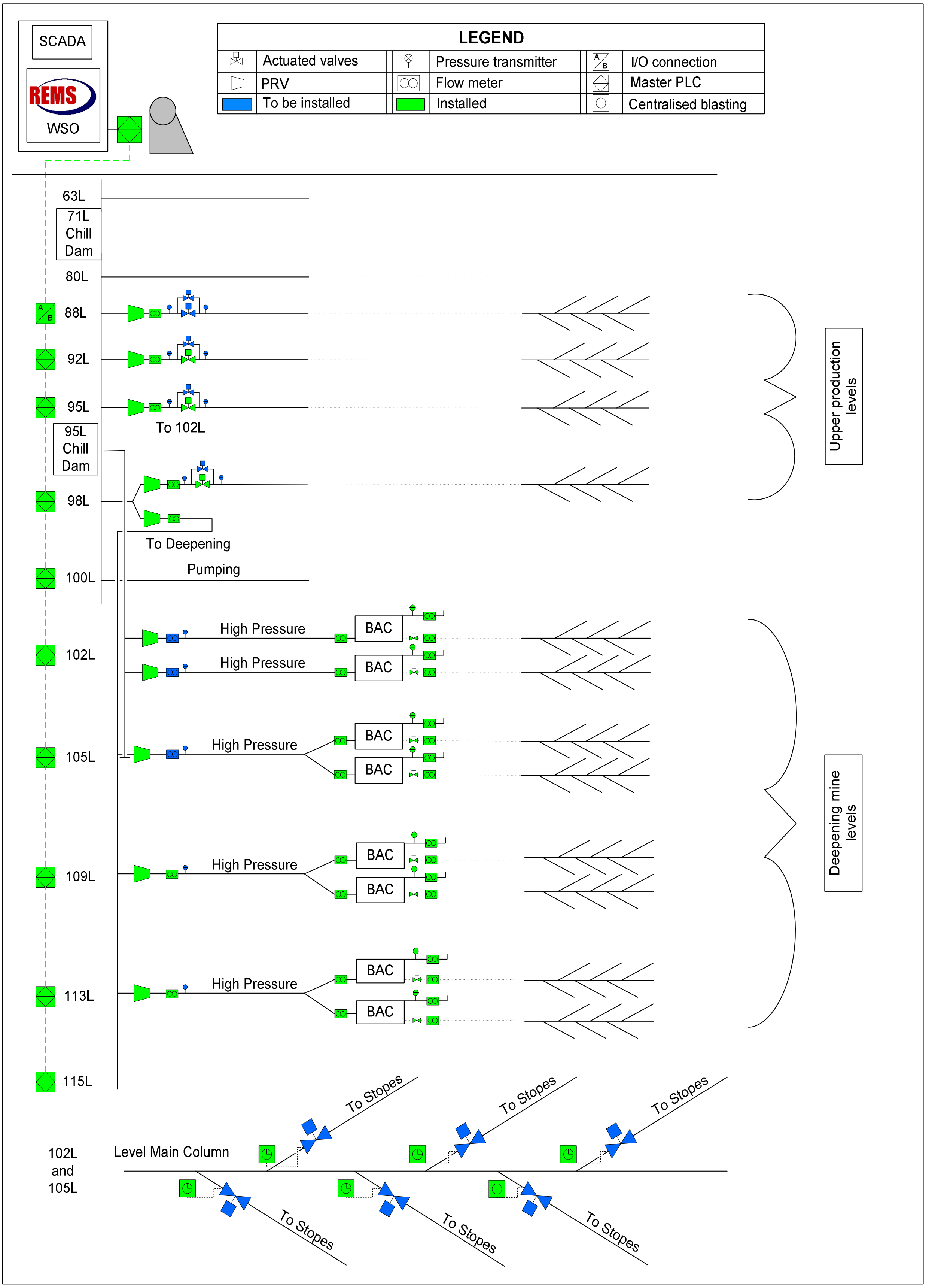


Figure 4-13: Kusasalethu equipment installation schematic

The pressure control philosophy is shown in Table 4-3. During nonproduction shifts the 250 mm butterfly valve is closed off completely and the globe control valve is used to control the downstream pressure. The downstream pressure is reduced from the normal 1 000 kPa in the production shift to 650 kPa during the nonproduction shifts.

Table 4-3: Weekday pressure control philosophy for Kusasalethu

Time	Mining activity	Butterfly valve	Globe valve	Downstream pressure
00:00-16:00	Sweeping and drilling	100% open	100% open	1 000 kPa
16:00-22:00	Blasting	0% open	Control enabled	650 kPa
22:00-00:00	Sweeping	100% open	100% open	1 000 kPa

The water supply to the production levels may not be stopped completely because the operation of the PRV requires a minimum flow rate. The minimum flow of each level is given as approximately 8 l/s and therefore the valves will be controlled accordingly. The pressure upstream of the installed control valve will increase significantly if the flow is reduced to a value less than the minimum. The upstream pressure will therefore be monitored throughout the control period.

The control philosophy will be programmed into the REMS-WSO platform which is connected to the mine's SCADA server via an OLE for Process Control (OPC) connection. A simplified layout of the mine's supply water reticulation is constructed using the REMS-WSO platform tools. The control room operator will be able to monitor the flow and pressure statuses on the REMS-WSO computer screen. The REMS-WSO platform layout is shown in Figure 4-14.

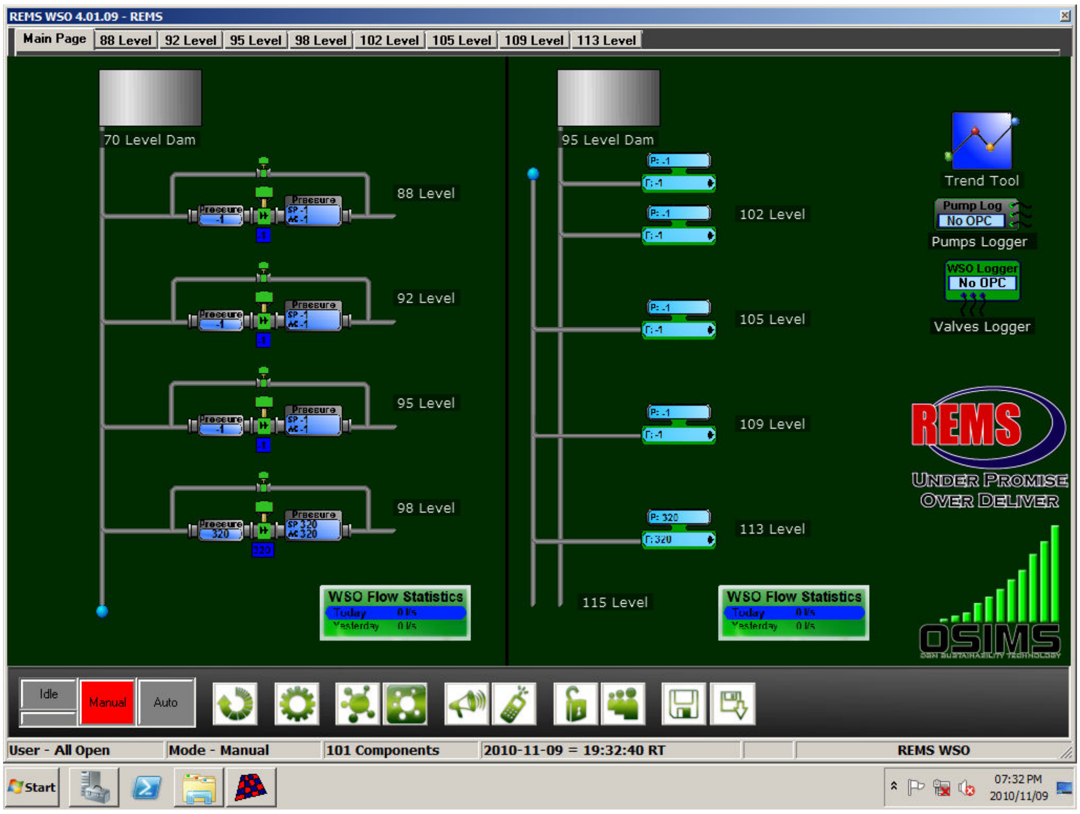


Figure 4-14: Kusasalethu REMS-WSO overview screen

4.3.5 RESULTS OF OPTIMISED WATER DEMAND

The expected water reduction is calculated using the baseline flow data. The estimated water reduction on the upper production levels (88 Level to 98 Level) and the Deepening levels will be calculated separately. This is because of the Deepening levels are only equipped with stope isolation valves and not pressure control valves. The respective flow rates of 88 Level, 92 Level, 95 Level and 98 Level may not be reduced below 8 l/s.

Pressure control will only be conducted during the blasting shift from 16:00 to 22:00. Therefore to determine the reduction during this period the baseline flow on each level will be reduced to a minimum flow rate of 10 l/s (2 l/s contingency). The expected total flow profile for the upper production levels is shown in Figure 4-15. A total reduction of 1.3 Ml water per day is expected from pressure control on the upper production levels. The 24-hour profile data is included in Appendix B.

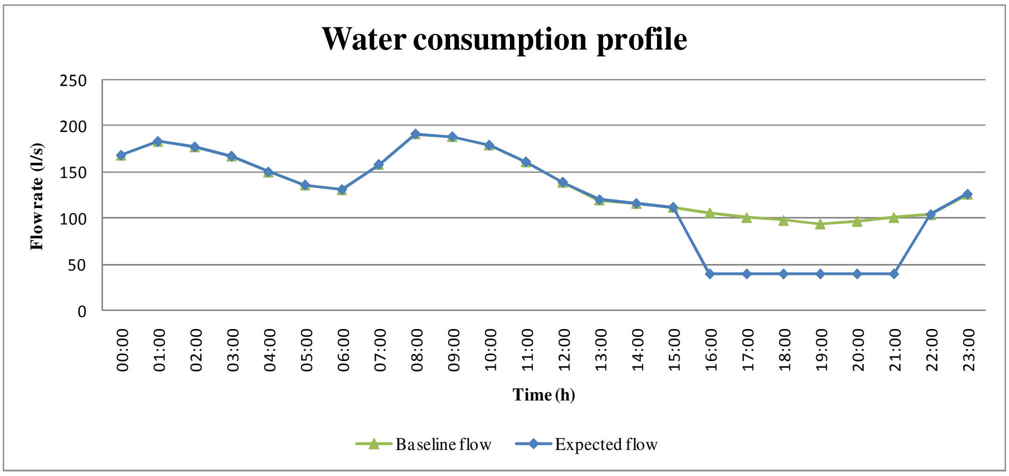


Figure 4-15: Expected combined flow to the upper production levels

Fifteen centralised blasting units are already installed and functional on the Deepening levels and therefore fifteen of the stope isolation valves will be considered in the reduction calculations. The flow rate of each individual stope is unknown, but the assumption is made that the flow to each stope area is at least 2 l/s throughout the day. The mining personnel exit the stope areas from 12:00 because the shift transport to surface starts from 12:30. There are circumstances where some of the production personnel exit the stopes no earlier than 14:00. Therefore the following assumptions are made:

- From 14:00 at least five of the stope valves are closed. Estimated flow reduction of 10 l/s.
- From 15:00 at least ten of the stope valves are closed. Estimated flow reduction of 20 l/s.
- From 16:00 to 22:00 all fifteen stope valves are closed. Estimated flow reduction of 30 l/s.

Therefore the expected total flow profile of the Deepening levels is calculated by subtracting the estimated flow reductions from the baseline flow profile for each respective time period. The expected flow profile for the Deepening levels is shown in Figure 4-16 with an expected daily reduction of 0.8 Ml water. The expected water reduction calculation of the stope valves on the Deepening levels is included in Appendix B.

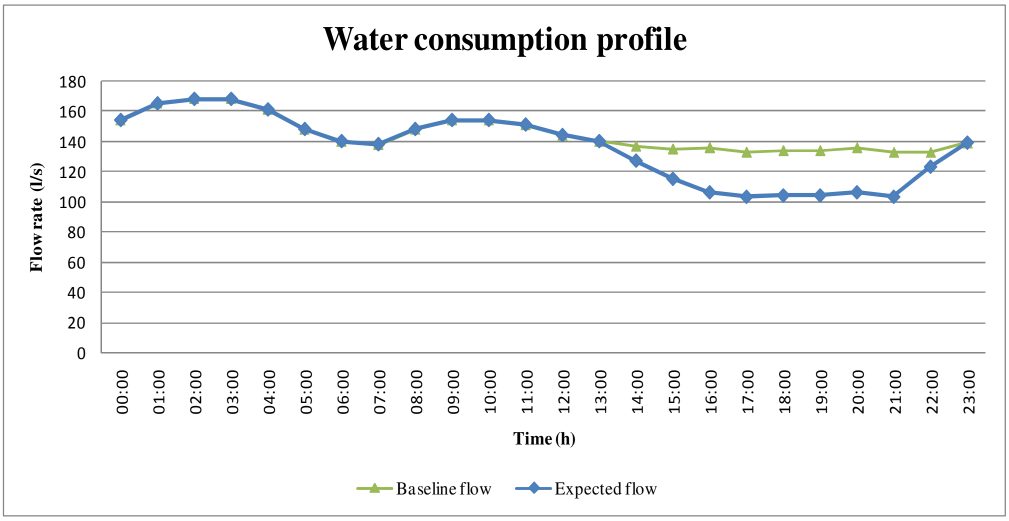


Figure 4-16: Expected combined flow to the Deepening mine levels

The expected total water reduction through the combination of stope isolation and pressure set-point control is therefore 2.1 Ml per day. The combined expected water consumption profile is shown in Figure 4-17.

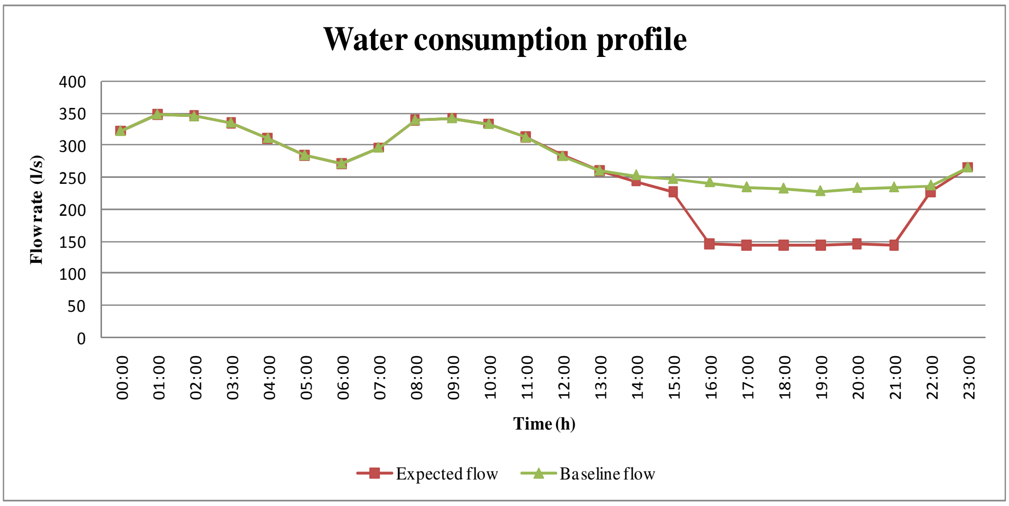


Figure 4-17: Expected combined flow to the production levels.

During the implementation of the study a significant number of water leaks were identified and repaired. The leaks range from small flange gasket leaks to large open-ended pipes and unattended running hoses. Some of the typical leaks identified and reported are shown in Table 4-4. The images of these leaks are shown in the example report included in Appendix A.

Table 4-4: Identified water leaks

Figure	Location	Leak type	Leak size (estimate)	Pipe size
1.	95 Level 37 crosscut entrance	Water hose used for mini freezer	10 mm	25 mm
2.	95 Level 37 crosscut at the raise	Hose left running, valve not functioning	7.5 mm	12 mm
3.	98 Level 31 crosscut entrance	Pipe leaking	10 mm	150 mm
4.	98 Level 42 crosscut	Manifold leaking	10 mm	-
5.	98 Level 38 crosscut at box 5	Pipe leaking	7.5 mm	150 mm
6.	98 Level 38 crosscut at box 2	Pipe leaking	5 mm	150 mm
7.	98 Level 28 crosscut entrance	Pipe leaking	10 mm	150 mm
8.	105 Level 34 crosscut entrance	Pipe leaking	5 mm	100 mm
9.	105 Level 34 crosscut box 2&3	Hose left running	10 mm	12 mm
10.	105 Level tram haulage backfill	Faulty pressure relief valve	10 mm	-

The implementation of the leak management realised a reduction in water consumption of approximately 7 Ml per day. This is a reduction of approximately 30% of the baseline water consumption. New leaks are still identified, logged and repaired on a daily basis. The average daily water consumption per month is shown in Figure 4-18. The daily production data for each month was obtained from the mine. The production data shows that the average daily production did not decrease during the implementation period.

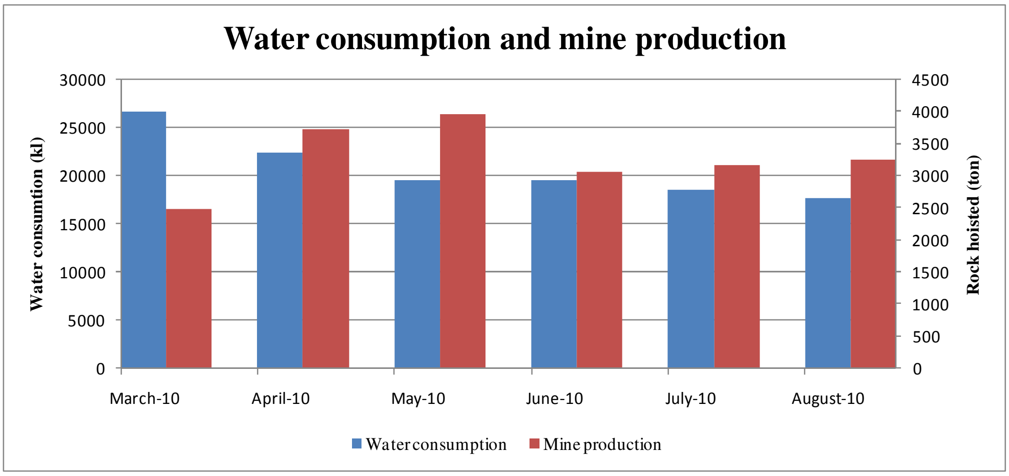


Figure 4-18: Monthly average water consumption for Kusasalethu

The large savings achieved by the leak management strategy has resulted in a significant decrease in water flow rate. This in turn has reduced the expected impact of the pressure control valves. The mine was unable to complete the commissioning of the control valves and stope isolation valves within the duration of this study. This was due to the long delivery time of the valves and the nonavailability of mine shutdown schedules.

The expected water reduction of pressure control and stope isolation is recalculated using the existing flow profile which includes the reduction already achieved by leak management. The recalculations are done in a similar manner, with the only difference being the baseline flow which is replaced by the current flow profile. The 24-hour profile data of the existing average water consumption and the newly expected flow profile data are included in Appendix B.

Figure 4-19 shows the expected flow reduction due to pressure control and stope isolation. An additional reduction of 1.6 Ml per day is expected when the pressure control and stope isolation valves on the production levels become operational. Although this is 0.5 Ml less than originally expected it is not seen as a problem because the total savings have increased significantly due to leak management. A total water reduction of 8.6 Ml per day is expected to be achieved after implementation of the project.

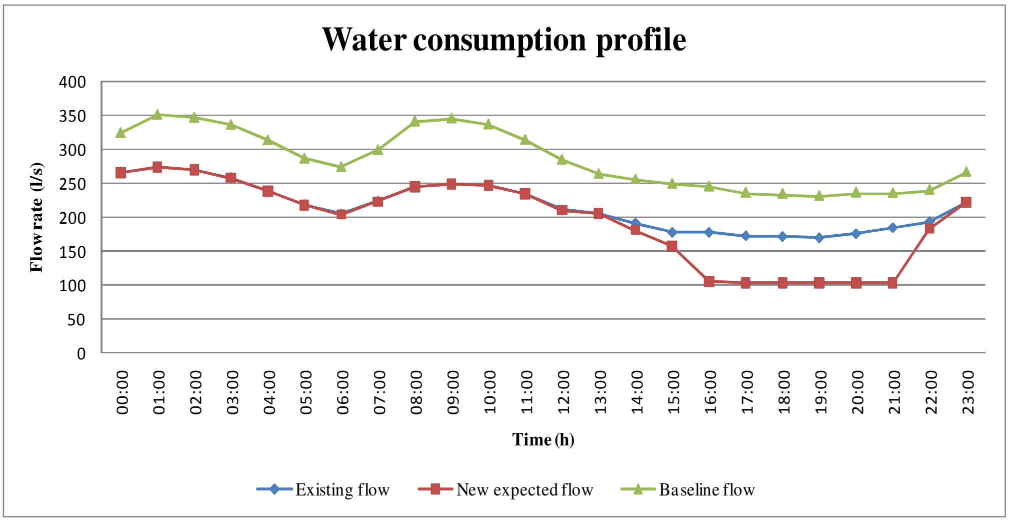


Figure 4-19: Combined production levels water consumption

The existing daily water reduction of approximately 7 Ml achieved through leak management is used to determine the accuracy of the savings quantification methodology. With the efficiency calculated as 75% the expected energy reduction is calculated using Equation 3-2 and Equation 3-3 as shown below.

The energy required to raise 7 Ml water per day from 100 Level is:

$Q = 291.67\ m^3/h$	(Average flow rate, 7 Ml/24)
$\rho = 1000\ kg/m^3$	(Constant)
$g = 9.81\ m/s^2$	(Constant)
$h = 3000\ m$	(Height from 100 Level to surface)
$\gamma \approx 0.75$	(Previously calculated)

$$P_{Theoretical} = \frac{Q\rho gh}{3.6\times10^6}$$

$$P_{Theoretical} = 238.4\ kW$$

$$E_{Theoretical} = 5.72\ MWh \qquad (P_{Theoretical} x\ 24)$$

$$E_{Actual} = \frac{E_{Theoretical}}{\gamma}$$

$$E_{Actual} \approx 76.3\ MWh \qquad \text{(Estimated actual savings achieved by leak management)}$$

The measured actual electrical energy consumption of the dewatering system for October 2010 was approximately 189 MWh per day. Thus the actual savings realised is 92 MWh per day based on the measured baseline which was 281 MWh. The accuracy of the expected energy reduction is therefore approximately 83%. The difference could be due to one of several reasons as listed below:

- Less fissure water pumped during this period, the assumption was made that the quantity of fissure water does not change.
- Better pump scheduling and less water to be pumped could have resulted in the mine running the more efficient pumps for a longer period.
- Fewer pumps run in parallel, the reduction in water to be pumped could have resulted in fewer pumps required to pump simultaneously in parallel which increases the efficiency.

The difference in the actual and expected reduction in electrical energy was however not investigated and is left for future work. Figure 4-20 shows the baseline electrical demand profile, the measured existing demand profile achieved through leak management (October 2010), and the expected post-implementation electrical demand profiles.

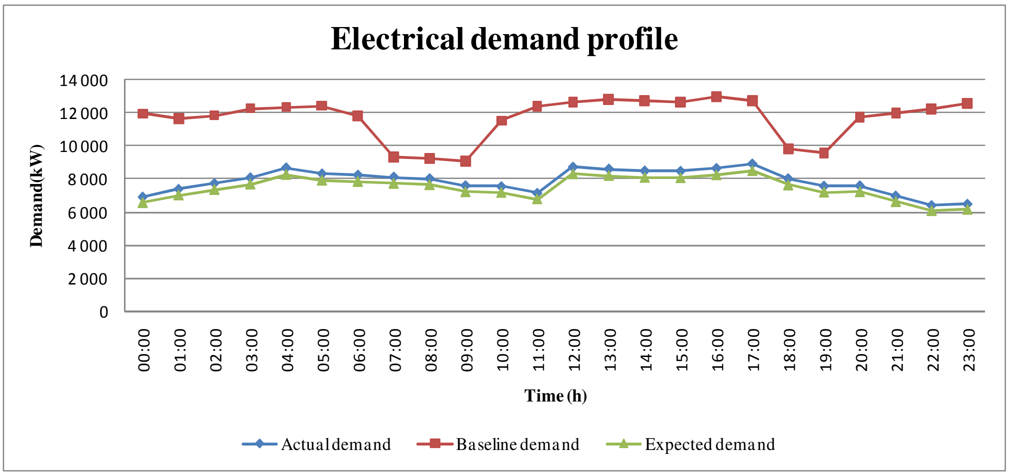


Figure 4-20: Electrical demand reduction of Kusasalethu

The expected reduction in electrical energy consumption results in a financial saving of R34 700 per day during high demand season, and R16 800 per day during the low demand season. This results in an estimated annual saving of R5 617 000 using the dewatering system. The financial saving is calculated using 2009/2010 Eskom electricity tariffs and assuming 22 weekdays per month. The calculations are included in Appendix B.

If the mine implements load shift on the dewatering system additional financial savings can be achieved. This will increase the total savings to R9 153 000 per annum. With less water to be pumped, the mine should be able to shift the electrical load from the Eskom peak periods by optimally utilising the storage dam capacities. The optimised load profile is shown in Figure 4-21. The financial savings calculation is included in Appendix B.

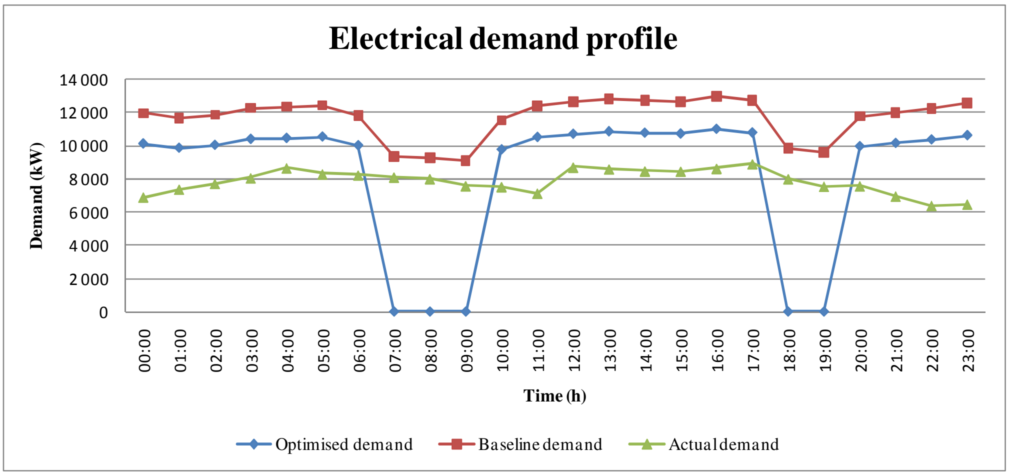


Figure 4-21: Optimised electrical demand profile for Kusasalethu

4.4 EXPANDING THE RESULTS TO OTHER MINES

Investigations were also conducted on various other deep-level mines to determine the potential savings that can be achieved by optimising the water reticulation system. The findings of the investigations resulted in DSM projects being implemented on these mines. The expected savings for each of these projects are shown in Table 4-5.

Table 4-5: Expected saving on other mines

Mine	Daily water	Daily energy	Expected	Annual saving
Mponeng	33 ML	480 MWh	39.6 MWh	R2 949 000
Kloof 1#	34 ML	633 MWh	45.6 MWh	R3 464 000
Kloof 7#	25 ML	330 MWh	39.6 MWh	R3 073 000
Ezulwini	70 ML	377 MWh	36 MWh	R2 858 000
Beatrix	15 ML	264 MWh	9.6 MWh	R781 000
				R13 120 000

Successful implementation of these projects will result in a total energy reduction of 170.4 MWh per day. This will reduce the average electrical power demand on the national electricity supply grid by 7.1 MW and realise a saving to the clients of R13 125 000 per annum. This excludes the possibilities of additional savings due to load shifting.

4.5 SUMMARY

In Case Study 1 a test was carried out on a typical deep-level gold mine to investigate the effect of water consumption reduction through water supply pressure control. The average water supply pressure is reduced in the nonproduction shift. A total reduction in water consumption of 1.4 Ml per day was achieved. The reduction in water consumption resulted in an average electrical energy reduction of 9.65 MWh per day.

In Case Study 2 the outcome of Case Study 1 is incorporated in an energy efficiency study implemented on a deep-level gold mine. Additional techniques to reduce the water consumption of the mine were also implemented. These techniques included the installation of globe control valves, a stope isolation system and the implementation of a water leak management strategy.

A water consumption reduction of approximately 7 Ml per day was achieved through the successful implementation of a leak management strategy. The implementation of the pressure control and stope isolation on the production levels is expected to reduce the water consumption by an additional 800 kl. Therefore a total reduction of 7.8 Ml is expected after implementation of all the savings initiatives.

The reduced water consumption resulted in a significant reduction in electrical energy consumed by the dewatering system. A saving in electrical energy consumption of 92 MWh per day is achieved through the implementation of the water supply optimisation study.

CHAPTER 5 :CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

South Africa has experienced difficulty in maintaining a sustainable electricity supply. It was also shown that the mining industry consumes a significant portion of the electricity generated by Eskom. The potential for energy efficiency initiatives in the mining industry were investigated and it was shown that the water reticulation system is one of the major consumers. The possibility of reducing the electricity consumption of the water reticulation system by optimising the water demand was investigated.

The water reticulation system is divided into two categories, namely the supply system and the dewatering system. It was shown that water is used primarily for cooling; drilling; and water jetting or sweeping purposes. High water pressures are experienced due to hydraulic pressure caused by the depth of the mine.

Water pressure is reduced by PRVs and distributed to the mining areas by an intricate water supply network. A control valve can be installed to provide the ability to reduce the water consumption on a level. Selecting the correct valve is important especially in the mining industry where high pressures could lead to damage resulting in production losses. Various types of valves used for water pressure control was discussed, as well as the common problems encountered in high pressure valve applications.

It was shown that the flow of a liquid through a hole in a pipe is a function of the size of the hole and the pressure of the fluid in the pipe. Therefore water wastage can be reduced by controlling the water pressure and by identifying and repairing water leaks. Another technique to reduce water wastage is by implementing a system that would automatically terminate the water supply to the working areas during nonproduction shifts.

A simplified method is discussed to calculate the efficiency of the dewatering system. This is then used to estimate the impact that the water reduction will have on the electrical energy consumption of the dewatering system. The Eskom TOU tariff structure is used to calculate the financial impact of a reduction in electrical energy consumption. These techniques are used to estimate the savings achieved.

The implementation of automated control systems is preferred to avoid human error and to maximise the savings and sustainability of the project. The REMS software is used in various DSM projects on mines and has proven to be a reliable and sustainable system.

The techniques discussed in Chapter 3 were implemented on two deep gold mines as case studies. The pressure control strategy was first tested on a mine that already had all the necessary equipment installed. A total daily reduction of 1.4 Ml water was achieved which realised a 9.65 MWh energy reduction. The total annual savings, based on Eskom Megaflex tariffs for 2009/2010, is estimated at R513 700.

Leak management had a significant influence on the water consumption of the mining levels in Case Study 2. The water flow was reduced significantly which subsequently resulted in a total daily reduction of 7 Ml water. This is a total reduction of approximately 30% of the average water consumed. This was unexpectedly high and may not be the case on other mines. The total electrical energy reduction through leak management is 92 MWh. The total annual saving, based on Eskom Megaflex tariffs for 2009/2010, is estimated at R5 617 000.

As mentioned in Chapter 2, the flow rate of the water is one of the criteria considered when selecting and sizing a valve. It is therefore recommended that the influence of water leak management be investigated prior to valve selection on water reduction projects if pressure control is considered. Inaccurate valve selection could result in underperformance or even equipment failure.

Valve control may appear to be too complex and expensive to implement when compared to the cost and simplicity of identifying and repairing leaks. The sustainability of an automated valve control system could be beneficial to ensure a constant saving whereas water leak occurrence is unpredictable. This is based on the assumption that the automated system will be maintained sufficiently.

It was shown during this study that the electrical energy consumption of a deep mine dewatering system can be reduced by optimising the demand of the water reticulation system. Further investigations have shown that a daily electrical energy reduction of 170 MWh can be achieved by implementing water demand reduction strategies at five other mines.

To put these savings into perspective the average electricity consumption of a middle-income household is estimated at 0.45 MWh/month [1]. This implies that a daily average of 170 MWh can provide electricity to approximately 11 000 middle-income households.

5.2 RECOMMENDATIONS FOR FURTHER WORK

During the study the potential savings on five additional mines were investigated. The water reducing techniques were however not implemented on these mines. Further investigations could be conducted on these mines to investigate and confirm the savings of the water reduction projects at these mines.

The sustainability of leak management, the tools used and the savings achieved on other mines could be investigated during future work.

The effects on the water reduction from the stope isolation system could not be confirmed during this study. It is therefore recommended as further work to investigate to what extent the stope isolation system can reduce the water consumption of a mine.

During the study water consumption was reduced by altering the water supply to the consumers. The equipment-specific requirement was not included in this study. The quantity of water consumed by the equipment, for example drills, water jets and air coolers, should be investigated and compared to the required water consumption to investigate additional reduction potential. This however is left as further work.

It is recommended that the potential of load shift created by a reduction in the water consumed be investigated. It was also seen during Case Study 2 that the actual energy reduction exceeded the expected energy reduction. The reason for this was not investigated during the study although certain possibilities were mentioned. This could also be included in further studies.

The influence that the water reduction has on the refrigeration system was also not included in this study. There are however certain possibilities that can be investigated. A reduction in water consumption could lead to better refrigeration or to an additional energy savings on the refrigeration plants. This should however be investigated and confirmed in further work.

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Appendix A

Mobile Information Collection System for Water Supply Optimisation Report

Generated by OSIMS (Special ETA Award Winner 2008) 10 November 2010

Table of Contents

Introduction

This daily report gives the status of the water supply system as generated by the Mobile Information Collection System for Water Supply Optimisation (MICS-WSO) for the Kusasalethu WSO project. Data collected on the mobile handheld units are used for leak management of the water supply system. This information can be used to improve the efficiency of the water supply system.

Please contact HVAC International (Pty) Ltd at reports-info@rems2.com should there be any queries or suggestions.

Existing water leaks

Table 1 summarises the leaks detected and documented by MICS-WSO for the period. Leaks documented in Table 1 have not been repaired by the time of generation of this document.

Repaired water leaks

Table 2 summarises the leaks that have already been repaired after being detected and documented by MICS-WSO.

Summary of existing water leaks

A. Table 1: Existing water leaks

	Date Detected	Shaft	Level	Location	Pipe Size [mm]	Leak Size [mm]	Leak Type	Responsible Person
1	2010-10-20	Kusasalethu	95	37 Cross-cut at the raise	25	10	Mini freezer	Miner 1
2	2010-10-20	Kusasalethu	95	37 Cross-cut at the raise	12	7.5	Hose	Miner 1
3	2010-10-20	Kusasalethu	98	28 Cross-cut Entrance	150	10	Pipe	Miner 2
4	2010-10-20	Kusasalethu	98	38 Cross-cut Box 2A	150	5	Pipe	Miner 3
5	2010-10-20	Kusasalethu	98	38 Cross-cut Box 5A	150	7.5	Pipe	Miner 3
6	2010-10-21	Kusasalethu	98	31 Cross-cut Entrance	150	10	Pipe	Miner 3
7	2010-10-21	Kusasalethu	98	42 Cross-cut	12	7.5	Hose	Miner 4
8	2010-10-21	Kusasalethu	98	42 Cross-cut		10	Manifold	Miner 4
9	2010-10-21	Kusasalethu	75	Cross-cut near sub-shaft	350	7.5	Pipe	Miner 5
10	2010-10-22	Kusasalethu	75	Cross cut near sub-shaft	250	10	Pipe	Miner 5
11	2010-10-22	Kusasalethu	75	Cross-cut past section vent door	350	15	Pipe	Miner 5
12	2010-10-22	Kusasalethu	105	Before backfill shaft	100	2.5	Pipe	Miner 6

Summary of repaired water leaks

B. Table 2: Repaired water leaks

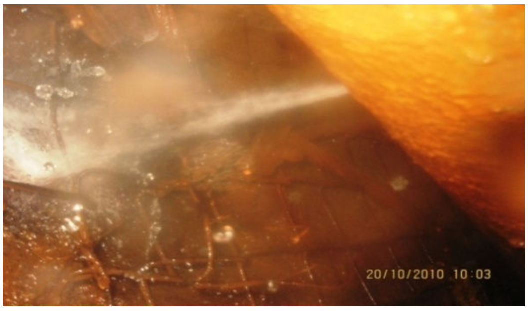
	Date Detected	Shaft	Level	Location	Pipe Size [mm]	Leak Size [mm]	Leak Type	Responsible Person
1	2010-10-07	Kusasalethu	105	35 Cross-cut	100	7.5	Pipe	Miner 6
2	2010-10-07	Kusasalethu	105	34 Cross-cut	100	5	Pipe	Miner 6
3	2010-10-11	Kusasalethu	98	34 Cross-cut between box 2 & 3	12	10	Hose	Miner 4

Leak Details

ID:	1	
Date Detected:	2010-10-20	
Shaft:	Kusasalethu	
Level:	95	
Location:	37 Cross-cut, Raise	
Pipe Size [mm]:	12	
Leak Size [mm]:	7.5	
Leak Type:	Tap	
Responsible Person:	Miner 1	
Comments:		

ID:	2	
Date Detected:	2010-10-20	
Shaft:	Kusasalethu	
Level:	95	
Location:	Cross-cut, Entrance	
Pipe Size [mm]:		
Leak Size [mm]:	10	
Leak Type:	Mini as freezer	
Responsible Person:	Miner 1	
Comments:		

ID:	3	
Date Detected:	2010-10-20	
Shaft:	Kusasalethu	
Level:	98	
Location:	28 Cross-cut, Entrance	
Pipe Size [mm]:	150	
Leak Size [mm]:	10	
Leak Type:	Pipe	
Responsible Person:	Miner 3	
Comments:		

ID:	4	
Date Detected:	2010-10-20	
Shaft:	Kusasalethu	
Level:	98	
Location:	38 Cross-cut, Box 2A	
Pipe Size [mm]:	150	
Leak Size [mm]:	5	
Leak Type:	Pipe	
Responsible Person:	Miner 3	
Comments:		

ID:	5	
Date Detected:	2010-10-20	
Shaft:	Kusasalethu	
Level:	98	
Location:	38 Cross-cut, Box 5A	
Pipe Size [mm]:	150	
Leak Size [mm]:	7.5	
Leak Type:	Pipe	
Responsible Person:	Miner 3	
Comments:		

ID:	6	
Date Detected:	2010-10-21	
Shaft:	Kusasalethu	
Level:	98	
Location:	31 Cross-cut, Entrance	
Pipe Size [mm]:	150	
Leak Size [mm]:	10	
Leak Type:	Pipe	
Responsible Person:	Miner 3	
Comments:		

ID:	7
Date Detected:	2010-10-21
Shaft:	Kusasalethu
Level:	98
Location:	42 Cross-cut
Pipe Size [mm]:	12
Leak Size [mm]:	7.5
Leak Type:	Hose
Responsible Person:	Miner 4
Comments:	

ID:	8
Date Detected:	2010-10-21
Shaft:	Kusasalethu
Level:	98
Location:	42 Cross-cut
Pipe Size [mm]:	
Leak Size [mm]:	10
Leak Type:	Manifold
Responsible Person:	Miner 4
Comments:	

ID:	9
Date Detected:	2010-10-21
Shaft:	Kusasalethu
Level:	75
Location:	Cross-cut, Sub-shaft
Pipe Size [mm]:	350
Leak Size [mm]:	7.5
Leak Type:	Pipe
Responsible Person:	Miner 5
Comments:	

ID:	10
Date Detected:	2010-10-22
Shaft:	Kusasalethu
Level:	75
Location:	Cross-cut, Sub-shaft
Pipe Size [mm]:	250
Leak Size [mm]:	10
Leak Type:	Pipe
Responsible Person:	Miner 5
Comments:	

ID:	11
Date Detected:	2010-10-22
Shaft:	Kusasalethu
Level:	75
Location:	Cross-cut, Vent door
Pipe Size [mm]:	350
Leak Size [mm]:	15
Leak Type:	Pipe
Responsible Person:	Miner 5
Comments:	

ID:	12
Date Detected:	2010-10-22
Shaft:	Kusasalethu
Level:	105
Location:	Backfill shaft
Pipe Size [mm]:	100
Leak Size [mm]:	2.5
Leak Type:	Pipe
Responsible Person:	Miner 6
Comments:	

Appendix B

Table B-1 below shows the legend and calculation method used to determine the flow to the respective mine levels as described in section 4.3.5 and shown in Table B-4 to Table B-6.

Table B-1: Kusasalethu flow calculation tables legend

Colour	Descriptions	Values
	Measured levels flow	A = Measured, B = Measured
	Total production levels flow	C = A + B
	Minimum allowed flow	A = Minimum per level x #levels
	At least 5 Stope are isolated	B = Measured – 10 l/s
	At least 10 Stopes are isolated	B = Measured – 20 l/s
	At least 15 Stopes are isolated	B = Measured – 30 l/s

Table B-3 below shows the legend and calculation method used to determine the electrical cost impact of the water reduction as described in section 4.3.5 and shown Table B-7 to Table B-9.

Table B-2: Kusasalethu cost calculation tables legend

Colour	Descriptions	Values
	Eskom off-peak demand period	
	Eskom standard demand period	
	Eskom peak demand period	
	Cost of electricity consumed	C = A x B
	Cost of electricity consumed	E = A x D
	Annual cost of electricity consumed	F = 22 x (3 x C + 9 x E)

Table B-3: Kusasalethu production levels baseline flow profile

Time	A 88-98 levels flow (l/s)		B Deepening levels flow (l/s)		C Total flow (l/s)
00:00	168		154		322
01:00	183		165		348
02:00	177		168		345
03:00	167		168		335
04:00	150		161		311
05:00	136		148		284
06:00	131		140		271
07:00	158		138		296
08:00	191		148		339
09:00	188		154		342
10:00	179		154		333
11:00	161	+	151	=	312
12:00	139		144		283
13:00	120		140		260
14:00	116		137		253
15:00	112		135		247
16:00	106		136		242
17:00	101		133		234
18:00	98		134		232
19:00	94		134		228
20:00	97		136		233
21:00	101		133		234
22:00	104		133		237
23:00	126		139		265
			Total		24.43 Ml

Table B-4: Kusasalethu production levels expected flow profile

	A		B		C
Time	Expected 88-98 levels flow (l/s)		Expected Deepening levels flow (l/s)		Expected total flow (l/s)
00:00	168		154		322
01:00	183		165		348
02:00	177		168		345
03:00	167		168		335
04:00	150		161		311
05:00	136		148		284
06:00	131		140		271
07:00	158		138		296
08:00	191		148		339
09:00	188		154		342
10:00	179		154		333
11:00	161	+	151	=	312
12:00	139		144		283
13:00	120		140		260
14:00	116		127		243
15:00	112		115		227
16:00	40		106		146
17:00	40		103		143
18:00	40		104		144
19:00	40		104		144
20:00	40		106		146
21:00	40		103		143
22:00	104		123		227
23:00	126		139		265
			Total		22.4 Ml

Table B-5: Kusasalethu production levels existing flow profile

Time	A Existing 88-98 levels flow (l/s)		B Existing Deepening levels flow (l/s)		C Existing total flow (l/s)
00:00	151		115		266
01:00	156		118		274
02:00	153		116		269
03:00	145		113		258
04:00	132		106		238
05:00	117		101		218
06:00	109		95		204
07:00	121		102		223
08:00	136		108		244
09:00	140		109		249
10:00	138		108		246
11:00	131	+	103	=	234
12:00	111		99		210
13:00	108		97		205
14:00	96		95		191
15:00	85		92		177
16:00	82		95		177
17:00	79		93		172
18:00	78		93		171
19:00	75		94		169
20:00	82		93		175
21:00	91		93		184
22:00	97		96		193
23:00	117		105		222
			Total		18.6 Ml

Table B-6: Kusasalethu new expected flow profile

Time	A Expected 88–98 levels flow (l/s)		B Expected Deepening levels flow (l/s)		C Expected total flow (l/s)
00:00	151		115		266
01:00	156		118		274
02:00	153		116		269
03:00	145		113		258
04:00	132		106		238
05:00	117		101		218
06:00	109		95		204
07:00	121		102		223
08:00	136		108		244
09:00	140		109		249
10:00	138		108		246
11:00	131	+	103	=	234
12:00	111		99		210
13:00	108		97		205
14:00	96		85		181
15:00	85		72		157
16:00	40		65		105
17:00	40		63		103
18:00	40		63		103
19:00	40		64		104
20:00	40		63		103
21:00	40		63		103
22:00	97		86		183
23:00	117		105		222
			Total		16.9 Ml

Table B-7: Electricity cost of baseline demand profile

	A	B	C	D	E	F
	Average weekday	High demand season		Low demand season		
Time	kWh	c/kWh	Cost	c/kWh	Cost	Annual Cost
00:00	11916	19.29	R 2 299	13.79	R 1 643	R 477 064
01:00	11609	19.29	R 2 239	13.79	R 1 601	R 464 773
02:00	11815	19.29	R 2 279	13.79	R 1 629	R 473 034
03:00	12243	19.29	R 2 362	13.79	R 1 688	R 490 183
04:00	12311	19.29	R 2 375	13.79	R 1 698	R 492 892
05:00	12409	19.29	R 2 394	13.79	R 1 711	R 496 815
06:00	11785	36.05	R 4 249	19.72	R 2 324	R 740 574
07:00	9332	138.58	R 12 933	32.19	R 3 004	R 1 448 421
08:00	9226	138.58	R 12 785	32.19	R 2 970	R 1 431 866
09:00	9053	138.58	R 12 547	32.19	R 2 914	R 1 405 120
10:00	11502	36.05	R 4 146	19.72	R 2 268	R 722 770
11:00	12376	36.05	R 4 462	19.72	R 2 441	R 777 732
12:00	12604	36.05	R 4 544	19.72	R 2 486	R 792 060
13:00	12781	36.05	R 4 608	19.72	R 2 521	R 803 182
14:00	12676	36.05	R 4 570	19.72	R 2 500	R 796 563
15:00	12621	36.05	R 4 550	19.72	R 2 489	R 793 107
16:00	12949	36.05	R 4 668	19.72	R 2 554	R 813 697
17:00	12693	36.05	R 4 576	19.72	R 2 503	R 797 652
18:00	9829	138.58	R 13 621	32.19	R 3 164	R 1 525 451
19:00	9544	138.58	R 13 227	32.19	R 3 072	R 1 481 271
20:00	11729	36.05	R 4 228	19.72	R 2 313	R 737 034
21:00	11960	36.05	R 4 312	19.72	R 2 359	R 751 571
22:00	12204	19.29	R 2 354	13.79	R 1 683	R 488 608
23:00	12506	19.29	R 2 412	13.79	R 1 725	R 500 685
Total			R 132 740		R 55 259	R 19 702 123

Table B-8: Electricity cost of existing demand profile

	A		B	C		D	E	F
	Average weekday		High demand season			Low demand season		
Time	kWh		c/kWh	Cost		c/kWh	Cost	Annual Cost
00:00	6 894		19.29	R1 330		13.79	R951	R 276 078
01:00	7 372		19.29	R1 422		13.79	R1 017	R 295 218
02:00	7 717		19.29	R1 489		13.79	R1 064	R 308 946
03:00	8 058		19.29	R1 554		13.79	R1 111	R 322 542
04:00	8 657		19.29	R1 670		13.79	R1 194	R 346 632
05:00	8 292		19.29	R1 600		13.79	R1 144	R 332 112
06:00	8 219		36.05	R2 963		19.72	R1 621	R 516 516
07:00	8 098		138.58	R11 223		32.19	R2 607	R 1 256 904
08:00	8 003		138.58	R11 091		32.19	R2 576	R 1 242 054
09:00	7 575		138.58	R10 498		32.19	R2 439	R 1 175 790
10:00	7 522		36.05	R2 712		19.72	R1 483	R 472 626
11:00	7 124		36.05	R2 568		19.72	R1 405	R 447 678
12:00	8 696		36.05	R3 135		19.72	R1 715	R 546 480
13:00	8 589		36.05	R3 097		19.72	R1 694	R 539 814
14:00	8 467		36.05	R3 053		19.72	R1 670	R 532 158
15:00	8 450		36.05	R3 046		19.72	R1 666	R 530 904
16:00	8 621		36.05	R3 108		19.72	R1 700	R 541 728
17:00	8 897		36.05	R3 208		19.72	R1 755	R 559 218
18:00	8 000		138.58	R11 087		32.19	R2 575	R 1 241 592
19:00	7 550		138.58	R10 464		32.19	R2 431	R 1 171 962
20:00	7 571		36.05	R2 729		19.72	R1 493	R 475 728
21:00	6 958		36.05	R2 509		19.72	R1 372	R 437 250
22:00	6 390		19.29	R1 233		13.79	R881	R 255 816
23:00	6 469		19.29	R1 248		13.79	R892	R 258 984
Total				R98 037			R38 456	R14 084 735

Table B-9: Electricity cost of optimised demand profile

	A		B	C		D	E	F
	Average weekday		High demand season			Low demand season		
Time	kWh		c/kWh	Cost		c/kWh	Cost	Annual Cost
00:00	10128		19.29	R 1 954		13.79	R 1 397	R 405 505
01:00	9867		19.29	R 1 903		13.79	R 1 361	R 395 057
02:00	10043		19.29	R 1 937		13.79	R 1 385	R 402 079
03:00	10407		19.29	R 2 008		13.79	R 1 435	R 416 655
04:00	10464		19.29	R 2 019		13.79	R 1 443	R 418 958
05:00	10547		19.29	R 2 035		13.79	R 1 455	R 422 293
06:00	10017		36.05	R 3 611		19.72	R 1 975	R 629 488
07:00	0		138.58	R 0		32.19	R 0	R 0
08:00	0		138.58	R 0		32.19	R 0	R 0
09:00	0		138.58	R 0		32.19	R 0	R 0
10:00	9776		36.05	R 3 525		19.72	R 1 928	R 614 354
11:00	10520		36.05	R 3 793		19.72	R 2 075	R 661 073
12:00	10713		36.05	R 3 862		19.72	R 2 113	R 673 251
13:00	10864		36.05	R 3 917		19.72	R 2 142	R 682 705
14:00	10774		36.05	R 3 884		19.72	R 2 125	R 677 079
15:00	10728		36.05	R 3 867		19.72	R 2 116	R 674 141
16:00	11006		36.05	R 3 968		19.72	R 2 171	R 691 642
17:00	10789		36.05	R 3 890		19.72	R 2 128	R 678 004
18:00	0		138.58	R 0		32.19	R 0	R 0
19:00	0		138.58	R 0		32.19	R 0	R 0
20:00	9969		36.05	R 3 594		19.72	R 1 966	R 626 479
21:00	10166		36.05	R 3 665		19.72	R 2 005	R 638 835
22:00	10373		19.29	R 2 001		13.79	R 1 431	R 415 317
23:00	10630		19.29	R 2 051		13.79	R 1 466	R 425 582
Total				R 57 483			R 34 114	R 10 548 496

Appendix C

Quotation Summary

PRIME - KLERKSDORP
Fax: 018 462 8762 **Phone: 018-462 7561**

Contact: **NICO**
RFQ:
Project:

ALPRET CONTROL SPECIALIST (Pty)Ltd

Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item	Rev	Qty	Description/Tags	Est. Del.
001		1	3 Inch GX Valve & Actr 88 LEVEL	182 Day
002		1	3 Inch GX Valve & Actr 92 LEVEL	182 Day
003		1	2 Inch GX Valve & Actr 95 LEVEL	182 Day
004		1	4 Inch GX Valve & Actr 98 LEVEL	182 Day

Notes:

1.THIS QUOTATION IS VALID FOR 30 DAYS FROM DATE OF QUOTATION.

2.THIS QUTATION IS SUBJECT TO OUR STANDARD CONDITIONS OF SALE WHICH IS AVAILABLE UPON REQUEST

3. QUOTED PRICES EXCLUDE V.A.T.

Contact @ JHBURG OFFICE Ph: 011-249-6700 - Fax: 011-474-5871
Contact @ DURBAN OFFICE Ph: 031 705 0450 - Fax: 031 705 0455
Contact @ SECUNDA OFFICE Ph: 017 634 6077 - Fax: 017 634 4408
Contact @ SASOLBURG OFFICE Ph: 016 920 4807 - Fax: 016 920 4815

Mar 07-1.2.39-alpjhbff 16 NOV 10 04:50:51 pm

SLIDING STEM CONTROL VALVE SPECIFICATION

Customer:	**PRIME - KLERKSDORP**	**ALPRET CONTROL SPECIALIST (Pty)Ltd**	
Contact:	**NICO**	Contact:	**Regy van Jaarsveld**
Reference:		Quote:	**086-H04393** Rev: **1** **20 JUL 10**
Project:		Data Sheet:	
Item:	**001** Rev: Qty: **1**		

Service:	
Tag:	**88 LEVEL**
Size and Type:	**3 Inch GX Valve & Actr**
Body Style:	**Globe**
Design Temp:	
Design Press:	
End Connect:	**Class 300**
In:	**RF Flanged**
Out:	**RF Flanged**
Material:	**CS 1.0619/WCC**
Ports:	**Single Port**
Flow Directn:	**Up**
Trim Number:	
Cage Matl:	**None**
Retainer Matl:	**None**
Bushing Matl:	
Seat Ring Matl:	**CF3M (SA351)**
VALVE PLUG	
Material:	**CF3M (SA351)**
Guiding:	**Port**
Balance:	**Unbalanced**
Shutoff Class:	**Class V**
Port Size:	**70 mm**
Characteristic:	**Equal %**
Stem Material:	**S31603**
Stem Size:	

Positioner Type:	**None**
Input Signal:	
Access:	
Gauges:	**None**
Action:	
Certification:	
Controller Type:	**None**
Action:	
Measure Element:	
Range:	
Output:	
Mounting:	
Airset:	
Mounting:	
Transducer:	**None**
Input Signal:	
Output Signal:	
Action:	
Mounting:	
Airset:	
Certifications:	
Line In:	**4.000 in, STD**
Line Out:	**4.000 in, STD**
Insulation:	
Service Cond:	
Process Fluid:	**Water**

Bonnet Style:	**Plain**
Boss Size:	
Packing:	**Live-load PTFE**
Access:	
Bolt, Bonnet:	**B7/2H (NCF2)**
PackFlg/Bltg:	
Actuator:	**Spg & Diaph**
Type/Size:	**GX/750**
Travel:	**40 mm**
Bench Set:	
Push Down To:	**Close**
Supply:	
To Actuator:	
Fails Valve:	**Fail Closed**
Handwheel:	**None**

		Minimum	Normal	Maximum
SG		1.000	1.000	1.000
T	deg C	10.000	10.000	10.000
P1	bar(g)	16.000	14.000	12.000
dP	bar	9.000	7.000	5.000
Q	l/m	540.000	600.000	960.000
Vlv Lpa	dB(A)	66.0	62.3	56.8
Cv		12.485	15.730	29.780
Km		0.883	0.883	0.883
% Open		32	38	57

Maximum Rated Flow Coefficient: **95.1 Cv**

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SLIDING STEM CONTROL VALVE SPECIFICATION

Customer: **PRIME - KLERKSDORP**
Contact: **NICO**
Reference:
Project:
Item: **002** Rev: Qty: **1**

ALPRET CONTROL SPECIALIST (Pty)Ltd
Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** **20 JUL 10**
Data Sheet:

Service:

Tag: **92 LEVEL**
Size and Type: **3 Inch GX Valve & Actr**

Body Style: **Globe**
Design Temp:
Design Press:
End Connect: **Class 300**
In: **RF Flanged**
Out: **RF Flanged**
Material: **CS 1.0619/WCC**
Ports: **Single Port**
Flow Directn: **Up**

Trim Number:
Cage Matl: **None**
Retainer Matl: **None**
Bushing Matl:
Seat Ring Matl: **CF3M (SA351)**
VALVE PLUG
Material: **CF3M (SA351)**
Guiding: **Port**
Balance: **Unbalanced**
Shutoff Class: **Class V**
Port Size: **46 mm**
Characteristic: **Equal %**
Stem Material: **S31603**
Stem Size:

Positioner Type: **None**
Input Signal:
Access:
Gauges: **None**
Action:
Certification:

Controller Type: **None**
Action:
Measure Element:
Range:
Output:
Mounting:
Airset:
Mounting:

Transducer: **None**
Input Signal:
Output Signal:
Action:
Mounting:
Airset:
Certifications:

Line In: **4.000 in, STD**
Line Out: **4.000 in, STD**
Insulation:
Service Cond:
Process Fluid: **Water**

Bonnet Style: **Plain**
Boss Size:
Packing: **Live-load PTFE**
Access:
Bolt, Bonnet: **B7/2H (NCF2)**
PackFlg/Bltg:

Actuator: **Spg & Diaph**
Type/Size: **GX/750**
Travel: **20 mm**
Bench Set:
Push Down To: **Close**
Supply:
To Actuator:
Fails Valve: **Fail Closed**
Handwheel: **None**

		Minimum	Normal	Maximum
SG		1.000	1.000	1.000
T	deg C	10.000	10.000	10.000
P1	bar(g)	16.000	14.000	12.000
dP	bar	9.000	7.000	5.000
Q	l/m	180.000	360.000	540.000
Vlv Lpa	dB(A)	59.2	57.8	53.6
Cv		4.161	9.438	16.751
Km		0.940	0.940	0.940
% Open		33	51	64

Maximum Rated Flow Coefficient: **43.7 Cv**

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SLIDING STEM CONTROL VALVE SPECIFICATION

Customer: **PRIME - KLERKSDORP**
Contact: **NICO**
Reference:
Project:
Item: **003** Rev: Qty: **1**

ALPRET CONTROL SPECIALIST (Pty)Ltd
Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** **20 JUL 10**
Data Sheet:

Service:

Tag: **95 LEVEL**
Size and Type: **2 Inch GX Valve & Actr**

Body Style: **Globe**
Design Temp:
Design Press:
End Connect: **Class 300**
In: **RF Flanged**
Out: **RF Flanged**
Material: **CS 1.0619/WCC**
Ports: **Single Port**
Flow Directn: **Up**

Trim Number:
Cage Matl: **None**
Retainer Matl: **None**
Bushing Matl:
Seat Ring Matl: **CF3M (SA351)**
VALVE PLUG
Material: **S31603**
Guiding: **Port**
Balance: **Unbalanced**
Shutoff Class: **Class V**
Port Size: **22 mm**
Characteristic: **Equal %**
Stem Material: **S31603**
Stem Size:

Positioner Type: **None**
Input Signal:
Access:
Gauges: **None**
Action:
Certification:

Controller Type: **None**
Action:
Measure Element:
Range:
Output:
Mounting:
Airset:
Mounting:

Transducer: **None**
Input Signal:
Output Signal:
Action:
Mounting:
Airset:
Certifications:

Line In: **4.000 in, STD**
Line Out: **4.000 in, STD**
Insulation:
Service Cond:
Process Fluid: **Water**

Bonnet Style: **Plain**
Boss Size:
Packing: **Live-load PTFE**
Access:
Bolt, Bonnet: **B7/2H (NCF2)**
PackFlg/Bltg:

Actuator: **Spg & Diaph**
Type/Size: **GX/225**
Travel: **20 mm**
Bench Set:
Push Down To: **Close**
Supply:
To Actuator:
Fails Valve: **Fail Closed**
Handwheel: **None**

		Minimum	Normal	Maximum
SG		1.000	1.000	1.000
T	deg C	10.000	10.000	10.000
P1	bar(g)	16.000	14.000	12.000
dP	bar	9.000	7.000	5.000
Q	l/m	60.000	180.000	240.000
Vlv Lpa	dB(A)	55.1	55.6	50.1
Cv		1.387	4.719	7.445
Km		0.921	0.921	0.921
% Open		33	68	80

Maximum Rated Flow Coefficient: **14.3 Cv**

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SLIDING STEM CONTROL VALVE SPECIFICATION

Customer: **PRIME - KLERKSDORP**
Contact: **NICO**
Reference:
Project:
Item: **004** Rev: Qty: **1**

ALPRET CONTROL SPECIALIST (Pty)Ltd
Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** **20 JUL 10**
Data Sheet:

Service:

Tag: **98 LEVEL**
Size and Type: **4 Inch GX Valve & Actr**

Body Style: **Globe**
Design Temp:
Design Press:
End Connect: **Class 300**
In: **RF Flanged**
Out: **RF Flanged**
Material: **CS 1.0619/WCC**
Ports: **Single Port**
Flow Directn: **Up**

Trim Number:
Cage Matl: **None**
Retainer Matl: **None**
Bushing Matl:
Seat Ring Matl: **CF3M (SA351)**
VALVE PLUG
Material: **CF3M (SA351)**
Guiding: **Port**
Balance: **Unbalanced**
Shutoff Class: **Class V**
Port Size: **70 mm**
Characteristic: **Linear**
Stem Material: **S31603**
Stem Size:

Positioner Type: **None**
Input Signal:
Access:
Gauges: **None**
Action:
Certification:

Controller Type: **None**
Action:
Measure Element:
Range:
Output:
Mounting:
Airset:
Mounting:

Transducer: **None**
Input Signal:
Output Signal:
Action:
Mounting:
Airset:
Certifications:

Line In: **4.000 in, STD**
Line Out: **4.000 in, STD**
Insulation:
Service Cond:
Process Fluid: **Water**

Bonnet Style: **Plain**
Boss Size:
Packing: **Live-load PTFE**
Access:
Bolt, Bonnet: **B7/2H (NCF2)**
PackFlg/Bltg:

Actuator: **Spg & Diaph**
Type/Size: **GX/750**
Travel: **40 mm**
Bench Set:
Push Down To: **Close**
Supply:
To Actuator:
Fails Valve: **Fail Closed**
Handwheel: **None**

		Minimum	Normal	Maximum
SG		1.000	1.000	1.000
T	deg C	10.000	10.000	10.000
P1	bar(g)	16.000	14.000	12.000
dP	bar	9.000	7.000	5.000
Q	l/m	2400.000	2700.000	3000.000
Vlv Lpa	dB(A)	72.5	68.9	61.7
Cv		55.492	70.788	93.064
Km		0.883	0.883	0.883
% Open		46	56	70

Maximum Rated Flow Coefficient: **128 Cv**

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Product Specification Report

PRIME - KLERKSDORP
Fax: 018 462 8762 Phone: 018-462 7561
Contact: **NICO**
RFQ:
Project:

ALPRET CONTROL SPECIALIST (Pty)Ltd
Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item: **001**
Tags: **88 LEVEL**
Desc.: **3 Inch GX Valve Actr**

FSGX2-7W2G4A/CL5

Valve Type :	**GX Valve & Actr**
Body Style :	**Globe**
Body Material :	**CS 1.0619/WCC**
Size :	**3 Inch**
Rating :	**Class 300**
End Conn :	**RF Flanged**
Flange face-to-face :	**Std Face to Face**
Flow :	**Up**
Valve Action :	**PDTC**
Characteristic :	**Equal %**
Port Size :	**70 mm**
Flow Char :	**Equal %**
Balance :	**Unbalanced**
Plug Material :	**CF3M (SA351)**
Stem Material :	**S31603**
Seat Ring Material :	**CF3M (SA351)**
Shutoff :	**Class V**
Travel :	**40 mm**
Guiding :	**Port**
Bonnet Gasket :	**Graphite Laminate**
Body/Bonnet Flg Bolting :	**B7/2H (NCF2)**
Packing :	**Live-load PTFE**
NACE :	**No**
Actuator Type :	**GX**
Actuator Style :	**Spg & Diaph**
Yoke Matl :	**Steel**
Actuator Size :	**750**
Dia Oper Press Range :	**4-6 bar(58-87Psig)**
Diaphragm Matl :	**Nitrile/Nylon**
Actuator Action :	**Air Opens/Spg Closes**
Bonnet Style :	**Plain**
Cage Material :	**None**
Fail Direction :	**Fail Down**
Fail Action :	**Fail Closed**
Min/Max Actr. Oper. Press :	**4-6 bar (58-87 Psig)**
Side Mtd Handwheel :	**Without**
Travel Stop :	**NONE**

PSPL-300

Processing Level :	**Level 3**
Standard Processing :	**Yes**
Fisher Mfg Cert. of Con. :	**Yes**
CMTR Press Bdry Pts :	**Yes**
C of C ASME/ASTM :	**Yes**
Assy Test Rpts :	**Yes**
Cert. of Conformance :	**Yes**

Contact @ JHBURG OFFICE Ph: 011-249-6700 - Fax: 011-474-5871
Contact @ DURBAN OFFICE Ph: 031 705 0450 - Fax: 031 705 0455
Contact @ SECUNDA OFFICE Ph: 017 634 6077 - Fax: 017 634 4408
Contact @ SASOLBURG OFFICE Ph: 016 920 4807 - Fax: 016 920 4815

Mar 07-1.2.39-alpjhbff 16 NOV 10 04:50:51 pm

Product Specification Report

PRIME - KLERKSDORP
Fax: 018 462 8762 Phone: 018-462 7561
Contact: **NICO**
RFQ:
Project:

ALPRET CONTROL SPECIALIST (Pty)Ltd
Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item: **002**
Tags: **92 LEVEL**
Desc.: **3 Inch GX Valve Actr**

FSGX2-7W2E3A/CL5

Valve Type : **GX Valve & Actr**
Body Style : **Globe**
Body Material : **CS 1.0619/WCC**
Size : **3 Inch**
Rating : **Class 300**
End Conn : **RF Flanged**
Flange face-to-face : **Std Face to Face**
Flow : **Up**
Valve Action : **PDTC**
Characteristic : **Equal %**
Port Size : **46 mm**
Flow Char : **Equal %**
Balance : **Unbalanced**
Plug Material : **CF3M (SA351)**
Stem Material : **S31603**
Seat Ring Material : **CF3M (SA351)**
Shutoff : **Class V**
Travel : **20 mm**
Guiding : **Port**
Bonnet Gasket : **Graphite Laminate**
Body/Bonnet Flg Bolting : **B7/2H (NCF2)**
Packing : **Live-load PTFE**
NACE : **No**
Actuator Type : **GX**
Actuator Style : **Spg & Diaph**
Yoke Matl : **Steel**
Actuator Size : **750**
Dia Oper Press Range : **4-6 bar(58-87Psig)**
Diaphragm Matl : **Nitrile/Nylon**
Actuator Action : **Air Opens/Spg Closes**
Bonnet Style : **Plain**
Cage Material : **None**
Fail Direction : **Fail Down**
Fail Action : **Fail Closed**
Min/Max Actr. Oper. Press : **2.5-6 bar(36-87Psig)**
Side Mtd Handwheel : **Without**
Travel Stop : **NONE**

PSPL-300

Processing Level : **Level 3**
Standard Processing : **Yes**
Fisher Mfg Cert. of Con. : **Yes**
CMTR Press Bdry Pts : **Yes**
C of C ASME/ASTM : **Yes**
Assy Test Rpts : **Yes**
Cert. of Conformance : **Yes**

Contact @ JHBURG OFFICE Ph: 011-249-6700 - Fax: 011-474-5871
Contact @ DURBAN OFFICE Ph: 031 705 0450 - Fax: 031 705 0455
Contact @ SECUNDA OFFICE Ph: 017 634 6077 - Fax: 017 634 4408
Contact @ SASOLBURG OFFICE Ph: 016 920 4807 - Fax: 016 920 4815

Product Specification Report

PRIME - KLERKSDORP
Fax: 018 462 8762 **Phone: 018-462 7561**
Contact: **NICO**
RFQ:
Project:

ALPRET CONTROL SPECIALIST (Pty)Ltd
Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item: **003** Desc.:**2 Inch GX Valve Actr**
Tags:**95 LEVEL**

FSGX2-5W2C2/CL5

Valve Type :	**GX Valve & Actr**
Body Style :	**Globe**
Body Material :	**CS 1.0619/WCC**
Size :	**2 Inch**
Rating :	**Class 300**
End Conn :	**RF Flanged**
Flange face-to-face :	**Std Face to Face**
Flow :	**Up**
Valve Action :	**PDTC**
Characteristic :	**Equal %**
Port Size :	**22 mm**
Flow Char :	**Equal %**
Balance :	**Unbalanced**
Plug Material :	**S31603**
Stem Material :	**S31603**
Seat Ring Material :	**CF3M (SA351)**
Shutoff :	**Class V**
Travel :	**20 mm**
Guiding :	**Port**
Bonnet Gasket :	**Graphite Laminate**
Body/Bonnet Flg Bolting :	**B7/2H (NCF2)**
Packing :	**Live-load PTFE**
NACE :	**No**
Actuator Type :	**GX**
Actuator Style :	**Spg & Diaph**
Yoke Matl :	**Steel**
Actuator Size :	**225**
Dia Oper Press Range :	**4-6 bar(58-87Psig)**
Diaphragm Matl :	**Nitrile/Nylon**
Actuator Action :	**Air Opens/Spg Closes**
Bonnet Style :	**Plain**
Cage Material :	**None**
Fail Direction :	**Fail Down**
Fail Action :	**Fail Closed**
Min/Max Actr. Oper. Press :	**3.8-6 bar(55-87Psig)**
Side Mtd Handwheel :	**Without**
Travel Stop :	**NONE**

PSPL-300

Processing Level :	**Level 3**
Standard Processing :	**Yes**
Fisher Mfg Cert. of Con. :	**Yes**
CMTR Press Bdry Pts :	**Yes**
C of C ASME/ASTM :	**Yes**
Assy Test Rpts :	**Yes**
Cert. of Conformance :	**Yes**

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Product Specification Report

PRIME - KLERKSDORP
Fax: 018 462 8762 Phone: 018-462 7561

ALPRET CONTROL SPECIALIST (Pty)Ltd

Contact: **NICO**
RFQ:
Project:

Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item: **004**
Tags: **98 LEVEL**

Desc.: **4 Inch GX Valve Actr**

FSGX2-9W2V4A/CL5

Valve Type : **GX Valve & Actr**
Body Style : **Globe**
Body Material : **CS 1.0619/WCC**
Size : **4 Inch**
Rating : **Class 300**
End Conn : **RF Flanged**
Flange face-to-face : **Std Face to Face**
Flow : **Up**
Valve Action : **PDTC**
Characteristic : **Linear**
Port Size : **70 mm**
Flow Char : **Linear**
Balance : **Unbalanced**
Plug Material : **CF3M (SA351)**
Stem Material : **S31603**
Seat Ring Material : **CF3M (SA351)**
Shutoff : **Class V**
Travel : **40 mm**
Guiding : **Port**
Bonnet Gasket : **Graphite Laminate**
Body/Bonnet Flg Bolting : **B7/2H (NCF2)**
Packing : **Live-load PTFE**
NACE : **No**
Actuator Type : **GX**
Actuator Style : **Spg & Diaph**
Yoke Matl : **Steel**
Actuator Size : **750**
Dia Oper Press Range : **4-6 bar(58-87Psig)**
Diaphragm Matl : **Nitrile/Nylon**
Actuator Action : **Air Opens/Spg Closes**
Bonnet Style : **Plain**
Cage Material : **None**
Fail Direction : **Fail Down**
Fail Action : **Fail Closed**
Min/Max Actr. Oper. Press : **4-6 bar (58-87 Psig)**
Side Mtd Handwheel : **Without**
Travel Stop : **NONE**

PSPL-300

Processing Level : **Level 3**
Standard Processing : **Yes**
Fisher Mfg Cert. of Con. : **Yes**
CMTR Press Bdry Pts : **Yes**
C of C ASME/ASTM : **Yes**
Assy Test Rpts : **Yes**
Cert. of Conformance : **Yes**

Z

SIZING CALCULATION

PRIME - KLERKSDORP
Fax: 018 462 8762 **Phone: 018-462 7561**
Contact: **NICO**
RFQ:
Project:

ALPRET CONTROL SPECIALIST (Pty)Ltd

Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item: 001 - VALVE/REGULATOR SIZING CALCULATION: Fisher Water
Item Desc: **3 Inch GX Valve Actr**
Tags: **88 LEVEL**

SERVICE & SIZING	Minimum	Normal	Maximum	Other
Inlet Pressure (bar(g))	16.000	14.000	12.000	12.000
Pressure Drop (bar)	9.000	7.000	5.000	0.500
Atm. Pressure (kPa(a))	101.600	101.600	101.600	101.600
Specific Gravity	1.000	1.000	1.000	1.000
Vapor Pressure (psia)	0.178	0.178	0.178	0.178
Temperature (deg C)	10.000	10.000	10.000	10.000
Liquid Flow Rate (l/m)	540.000	600.000	960.000	540.000
Recovery Coefficient, Km	0.883	0.883	0.883	0.883
Cavitation Index, Kc	0.890	0.890	0.890	0.890
Sizing Coefficient, Cv	12.485	15.730	29.780	52.973
dP Allowable (bar)	15.025	13.258	11.491	11.491
dP Cavitation (bar)	15.133	13.353	11.573	11.573
Cavitrol Trim Application Ratio, Ar	0.529	0.467	0.385	0.038
Rc	0.958	0.958	0.958	0.958
Notes:				

NOISE CALCULATION				
Fisher Valve/Reg Trim Type	STANDARD	STANDARD	STANDARD	STANDARD
Downstream Pipe Size (in)	4.000	4.000	4.000	4.000
Downstream Pipe Schedule	STD	STD	STD	STD
Valve/Reg LpA (SPL) (dB(A))	66.0	62.3	56.8	< 50

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Contact @ SASOLBURG OFFICE Ph: 016 920 4807 - Fax: 016 920 4815

SIZING CALCULATION

PRIME - KLERKSDORP
Fax: 018 462 8762 Phone: 018-462 7561
Contact: **NICO**
RFQ:
Project:

ALPRET CONTROL SPECIALIST (Pty)Ltd
Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item: 002 - VALVE/REGULATOR SIZING CALCULATION: Fisher Water
Item Desc: **3 Inch GX Valve Actr**
Tags: **92 LEVEL**

SERVICE & SIZING	**Minimum**	**Normal**	**Maximum**	**Other**
Inlet Pressure (bar(g))	16.000	14.000	12.000	12.000
Pressure Drop (bar)	9.000	7.000	5.000	0.500
Atm. Pressure (kPa(a))	101.600	101.600	101.600	101.600
Specific Gravity	1.000	1.000	1.000	1.000
Vapor Pressure (psia)	0.178	0.178	0.178	0.178
Temperature (deg C)	10.000	10.000	10.000	10.000
Liquid Flow Rate (l/m)	180.000	360.000	540.000	180.000
Recovery Coefficient, Km	0.940	0.940	0.940	0.940
Cavitation Index, Kc	0.890	0.890	0.890	0.890
Sizing Coefficient, Cv	4.161	9.438	16.751	17.657
dP Allowable (bar)	15.999	14.117	12.236	12.236
dP Cavitation (bar)	15.133	13.353	11.573	11.573
Cavitrol Trim Application Ratio, Ar	0.529	0.467	0.385	0.038
Rc	0.958	0.958	0.958	0.958

Notes:

NOISE CALCULATION				
Fisher Valve/Reg Trim Type	STANDARD	STANDARD	STANDARD	STANDARD
Downstream Pipe Size (in)	4.000	4.000	4.000	4.000
Downstream Pipe Schedule	STD	STD	STD	STD
Valve/Reg LpA (SPL) (dB(A))	59.2	57.8	53.6	< 50

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SIZING CALCULATION

PRIME - KLERKSDORP
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ALPRET CONTROL SPECIALIST (Pty)Ltd

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Project:

Contact: **Regy van Jaarsveld**
Quote: **086-H04393** Rev: **1** Date: **20 JUL 10**

Item: 003 - VALVE/REGULATOR SIZING CALCULATION: Fisher Water
Item Desc: **2 Inch GX Valve Actr**
Tags: **95 LEVEL**

SERVICE & SIZING	**Minimum**	**Normal**	**Maximum**	**Other**
Inlet Pressure (bar(g))	16.000	14.000	12.000	12.000
Pressure Drop (bar)	9.000	7.000	5.000	0.500
Atm. Pressure (kPa(a))	101.600	101.600	101.600	101.600
Specific Gravity	1.000	1.000	1.000	1.000
Vapor Pressure (psia)	0.178	0.178	0.178	0.178
Temperature (deg C)	10.000	10.000	10.000	10.000
Liquid Flow Rate (l/m)	60.000	180.000	240.000	60.000
Recovery Coefficient, Km	0.921	0.921	0.921	0.921
Cavitation Index, Kc	0.890	0.890	0.890	0.890
Sizing Coefficient, Cv	1.387	4.719	7.445	5.885
dP Allowable (bar)	15.671	13.828	11.985	11.985
dP Cavitation (bar)	15.133	13.353	11.573	11.573
Cavitrol Trim Application Ratio, Ar	0.529	0.467	0.385	0.038
Rc	0.958	0.958	0.958	0.958
Notes:				

NOISE CALCULATION				
Fisher Valve/Reg Trim Type	STANDARD	STANDARD	STANDARD	STANDARD
Downstream Pipe Size (in)	4.000	4.000	4.000	4.000
Downstream Pipe Schedule	STD	STD	STD	STD
Valve/Reg LpA (SPL) (dB(A))	55.1	55.6	50.1	< 50

SIZING CALCULATION

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Fax: 018 462 8762   Phone: 018-462 7561
Contact: **NICO**
RFQ:
Project:

ALPRET CONTROL SPECIALIST (Pty)Ltd

Contact: **Regy van Jaarsveld**
Quote: **086-H04393**   Rev: **1**   Date: **20 JUL 10**

Item: 004 - VALVE/REGULATOR SIZING CALCULATION: Fisher Water
Item Desc: **4 Inch GX Valve Actr**
Tags: **98 LEVEL**

SERVICE & SIZING	**Minimum**	**Normal**	**Maximum**	**Other**
Inlet Pressure (bar(g))	16.000	14.000	12.000	12.000
Pressure Drop (bar)	9.000	7.000	5.000	10.000
Atm. Pressure (kPa(a))	101.600	101.600	101.600	101.600
Specific Gravity	1.000	1.000	1.000	1.000
Vapor Pressure (psia)	0.178	0.178	0.178	0.178
Temperature (deg C)	10.000	10.000	10.000	10.000
Liquid Flow Rate (l/m)	2400.000	2700.000	3000.000	2400.000
Recovery Coefficient, Km	0.883	0.883	0.883	0.883
Cavitation Index, Kc	0.890	0.890	0.890	0.890
Sizing Coefficient, Cv	55.492	70.788	93.064	52.645
dP Allowable (bar)	15.025	13.258	11.491	11.491
dP Cavitation (bar)	15.133	13.353	11.573	11.573
Cavitrol Trim Application Ratio, Ar	0.529	0.467	0.385	0.769
Rc	0.958	0.958	0.958	0.958
Notes:				

NOISE CALCULATION				
Fisher Valve/Reg Trim Type	STANDARD	STANDARD	STANDARD	STANDARD
Downstream Pipe Size (in)	4.000	4.000	4.000	4.000
Downstream Pipe Schedule	STD	STD	STD	STD
Valve/Reg LpA (SPL) (dB(A))	72.5	68.9	61.7	78.1

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