Advances made in mine water management at Sasol Mining during the past eight years

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ABSTRACT

In 1996, Sasol Mining embarked on a process aimed at the development and implementation of mine water management strategies that would minimise potential operational and closure water impacts and associated water management costs. Technical studies were conducted in a focussed and systematic manner to develop an understanding of the factors and processes that drive underground water balances and quality. This understanding was then used to develop various water management "tools" that aid the mines in water management during the operational and closure phases of the mines. These "tools" are being integrated with the established suite of planning and mine design tools used for the technical and financial planning, development, and management of the mines. The implementation of mitigation measures and revised mining practices is supported by this process, and strategic mine water management related decisions are now beginning to be made as a result. Mine design and scheduling has adapted to ensure that a reduced net discharge of water from the mines is achieved by restricting in-flow and optimising underground storage. Furthermore, this capacity development process has established water management as an integral element of developing sustainable mining practices at Sasol Mining's collieries. This paper discusses the reasoning process involved in the development of the present level of knowledge, the resultant knowledge systems and tools, and the lessons learned along the way.

INTRODUCTION

In the design phase of the Secunda project during the early 1970's, a geohydrological assessment by Hodgson et al (1979), indicated that groundwater in-flow into the planned mines could pose a potential problem for mining activities. It was foreseen that groundwater would drain more freely into the mine workings, as the mines proceeded to open up large underground areas using high extraction mining methods that would fracture the overlying strata. The resultant influx of water could lead to excessive volumes of water in the mine workings and would threaten continued operations. This report went largely unheeded as no immediate threat arose during the period that the mines were established and brought up to full production capacity. However, in the late 1980s, the ingress of water into the workings started to pose a threat to the daily operation of the four then-established mines at Secunda. This nuisance water was dealt with by transferring it to abandoned worked-out portions of the underground workings. The potential of this water management strategy was soon exhausted when the water again appeared in the main intake and return roadways to interrupt operations by threatening the continued operation of vital infrastructure.

The response to this re-emerged threat was to install larger capacity pumps and piping in the mines and to establish an integrated transfer piping system for handling water above ground. This integrated system transferred excess mine water to a holding dam that was constructed on the surface for this purpose. These measures again provided only a temporary solution.

The dynamics of the mechanism of in-flow was not well understood by the planning and operations staff at the mines. No allowance was therefore made for the seasonal variation of in-flow driven by annual and longer-cycle variations in rainfall and the annual increase in the mined area that was driving an escalating rate of increase in the flow to the workings. Without having this understanding of the dynamics of the water make mechanism, most engineered solutions would be short lived.

During 1994, the Department of Water Affairs and Forestry wrote a letter to Sasol indicting that the Department was aware of some of the underground mine water problems experienced by Sasol Mining and that Sasol was at risk of not getting future permits if an Integrated Water Management Plan for the Sasol Secunda Operations was not developed. EMPR documents developed for the four mines then in existence also started to highlight their lack of understanding regarding the effects of underground mining on the receiving water environment.

In 1995, the problem reappeared once more in the form of a major flooding incident at the Twistdraai Colliery, resulting in a two week stoppage of operations. Two similar but less severe incidents also occurred at the Bosjesspruit Mine. Fortunately, no injury to personnel resulted from these events; however, financial losses were substantial.

In response to these incidents, a process was initiated to develop sufficient understanding of the mechanisms driving the ingress of water into the mines in order to forecast the extent of future water in-flow. By creating an understanding of the driving mechanisms, it was envisaged that operational water balances could be managed to avoid such incidents in the future. An understanding of the driving mechanisms would also enable the design of more lasting engineering solutions.

THE MINE WATER MANAGEMENT CAPACITY DEVELOPMENT PROGRAM

Since 1996, Sasol Mining has been progressively developing the capacity to both understand and manage the impact that underground mining has on the natural water environment. This program addressed the development of the capacity to deal with water management at individual mines as well as collectively among the mines in order to address the combined impact on the downstream affected catchments. A water management strategy based on a hierarchy of actions was adopted from the National Water Act and modified to accommodate mining practices. The elements of the modified hierarchy in order of priority are:

- Reduction at-source
- Storage management
- Re-use and recycling of excess water
- Treatment, if unsuitable for re-use or discharge to the environment

- Disposal in an acceptable manner

Over the seven year period to date, the primary focus has been to develop an understanding of the mechanisms that drive the in-flow of water into the mines in response to the various mining methods used, and to develop the knowledge, means and competence to prepare forecasts and to manage daily, monthly and annual water balances. This focus on volume and flows has been deliberate as there has been, and still exists, a need to ensure that water ingress is managed in a manner that will ensure the continuation of daily operations. The main objective was thus to ensure continued operations, free of interruption by groundwater in-flow and focussed on proactively taking actions to avoid adverse operational impacts.

As more knowledge of the interaction of mining with the water resource and groundwater structures developed, it was realised that the salt load associated with acid rock drainage (ARD) processes in the coal and overlying strata, was a more severe threat to the longer term viability of mining operations than the prospect of further flooding incidents. This realisation was dramatically emphasised when it became necessary to build an evaporator/crystalliser (EC) plant in 2003 to process the brine from an electro-dialysis reversal (1999) plant previously constructed.

The combined capital cost of around R 400 Million for this facility to treat a design through-put of 9Mℓ/day, resulted in a new focus on learning more about the ARD potential and geochemistry of mine water in the underground workings and overlying geological strata. Forecasts of water ingress for the next 20 years have shown that a second investment of this magnitude would be required (2005) shortly after the planned commissioning of the first EC plant (2003), if no alternative management interventions are implemented to reduce water ingress and deterioration.

Knowledge creation and learning now moved towards creating an in depth understanding of both the water volume driving mechanisms and the water chemistry driving mechanisms in order to devise means to change behaviour and mining practices so that future potentially debilitating treatment costs could be avoided. Currently, the focus of capacity development at Sasol Mining to manage mine water is on the implementation of specific operational and closure plans that are aimed at integration of mine water management tools and understanding with mine planning and business processes.

The current phase of the Capacity Development Program (2002/2003) has started to address the issue of ARD processes and mine water geochemistry. A number of projects with a similar focus, but initiated through the Water Research Commission (WRC) and Coaltech, have also been in progress for the past three years. Both the WRC and Coaltech have supported research into various aspects of understanding the chemical interaction of mining and the natural water system. Industry representatives, consultants and academics who served on the research management committees have all played a role in the development of a greater understanding of this mining challenge.

The development of a capacity to deal with the water issues at mines has been driven primarily as a response to crises and in recognition of medium-term issues. At Sasol Mining, the focus has been on developing the capacity to forecast and manage operational water balances to avoid incurring unacceptable costs. Some work has also been done to include sound water management practice in the design of future mines and extensions to existing mines.

PHASED CAPACITY DEVELOPMENT APPROACH

The Capacity Development Program at Sasol Mining has followed a phased approach over the last 7 years. Three distinct phases have been identified, which are schematically presented in Figure 1.

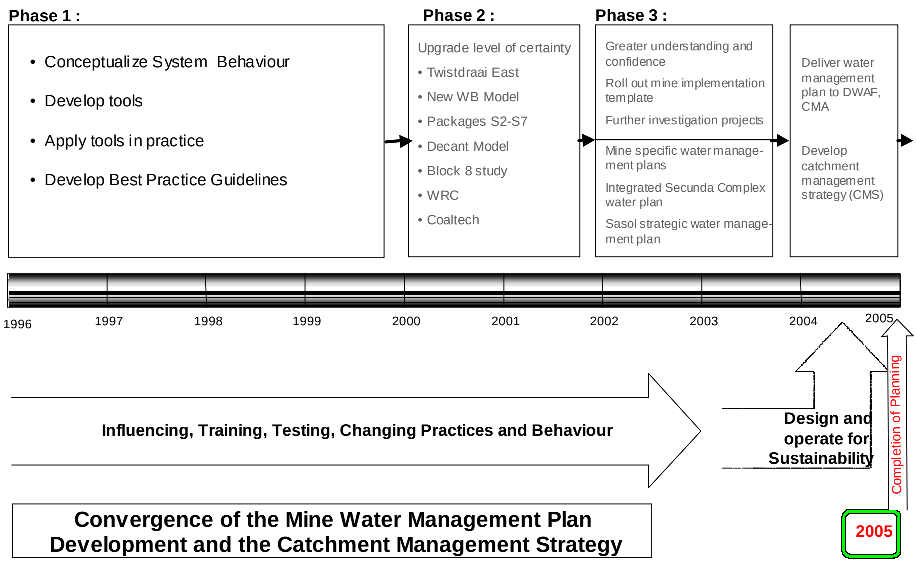

Figure 1. Schematic representation of phased approach in water management capacity development at Sasol Mining

Each phase was unique in its approach and the subsequent phases build on the progress that was made in the preceding phase. A brief description of the three phases is provided below and gives specific reference to the technical work constituting the phases as well as the water management "tools" that were developed as part of the technical studies.

PHASE 1

The initial focus in Phase 1 was on understanding the flow of water to the underground workings. This led to the development of an underground water mass balance modelling tool that helps predict and map the ingress of water and management thereof for the life of a mine. It gave insight to the relationship between the broad-scale effects of mining and the water environment and, hence, the scale of environmental liability. Phase 1 also provided focus for investigations/studies/research into factors that will affect the outcome of decisions taken.

Two Work Packages, A and B, were conducted based on sensitivity analyses of the water balances developed for the underground mines. Figure 2 shows a typical water balance for the underground mining sections. Work Package "A" underscored the need for focussed understanding of each discreet pathway. From top to bottom of the stratigraphic column, the prioritised work packages were:

- Soils – Storage, attenuation & recharge
- Unsaturated zone – Recharge & attenuation
- Drainage lines – Catchment losses & recharge
- Ponding on subsided ground – Attenuation & recharge
- Karoo aquifer – Conduits/pathways
- Faults and dykes within the rock mass – Conduits/Pathways
- Storage in goaf – Receptor

Work Package B underscored the need for a focussed understanding of the factors affecting the quality of water in underground workings. This particular study was based on available geochemical data and understanding, including water quality monitoring data, coal characteristics, current research and experience. The report aimed at documenting possible processes and effects of mining operations on compartment water quality and was used to develop the first broad Best Practice Guidelines for Water Quality Management.

With respect to water management tools, spreadsheet based water balance models were developed for existing mines. These water balance models are sensitive to mining method and mine layout, and were used in mine planning to optimise the creation of underground water storage during the operational phase.

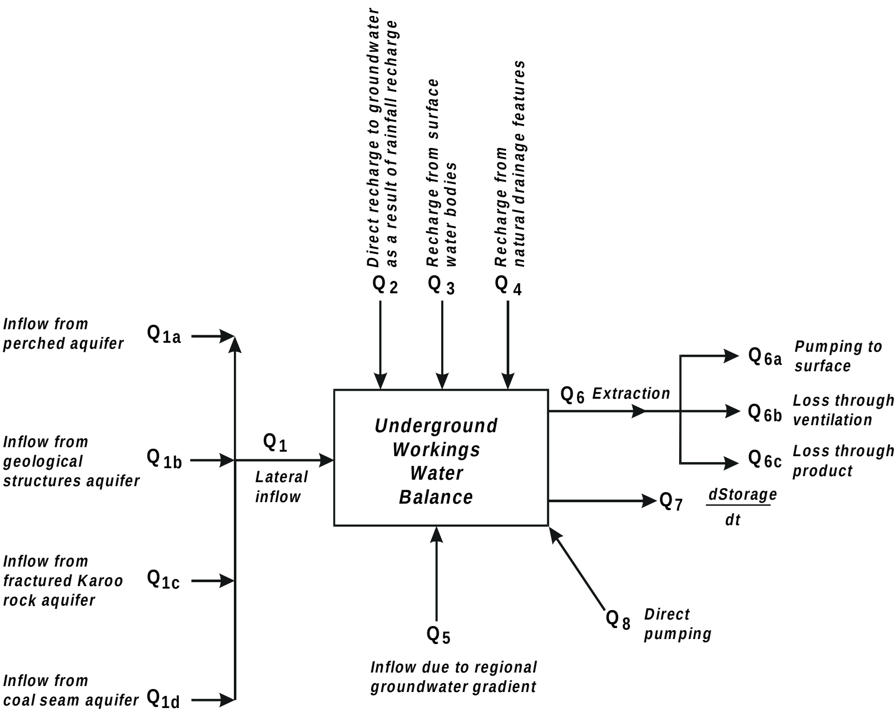

Figure 2. Schematic representation of underground mine water balance

PHASE 2

The Phase 2 Work Packages built on the findings of the Phase 1 work and were primarily aimed at a more detailed understanding of site specific flow and quality parameters already found to be critical to the water balances. The work packages were further aimed at using the existing knowledge and understanding to quantify flow parameters at the compartment level.

Furthermore, a Best Practice Guideline document was developed as part of a drive to provide a suite of planning and operational tools to more effectively manage underground workings and related water balances.

The Phase 2 Work Packages consisted of nine technical studies, five aimed at source determination and four on pathway determination. The five source determination studies included:

- Understanding the unsaturated zone and its contribution to net recharge
- Understanding the effects of different soil types on net recharge potential
- Establishment of a detailed rainfall monitoring network
- Studying the effects of surface subsidence and ponding on net recharge
- Studying the effects of drainage lines on underground water balances

The four Work Packages focussing on pathway characterisation included:

- Karoo aquifer geohydrology
- Studying the effects of faults and dykes on groundwater inflow
- Studying the parameters that drive storage
- Study of different decant mechanisms and the effects on post-closure or residual impacts (generic decant model)

Water management tools that were developed during the Phase 2 work include a stand-alone software application of the spreadsheet underground water balances, called UWMS (Underground Water Management System). UWMS was installed at all mines and populated with mine specific data. The technology and understanding were developed to generate recharge potential maps of mine areas. These “maps” allocate, for each surface area comprising a mine section, a recharge potential based on the findings of the specialist studies on soil, the vadose zone, drainage lines, geology, mining method, and depth of workings. The Best Practice Guideline document was further developed and updated with the findings and recommendations of the specialist studies. A document management system was also developed to act as a tool for mine planners to electronically find relevant mine water management information. This information could be in the form of a Best Practice Guideline or a specialist study report.

PHASE 3

Phase 3 had a strong bias towards implementation of effective water management practices at the mine and focussed on transfer of knowledge to mines as well as ensuring the continued development of mine water management and planning tools. The final deliverable for the Phase 3 work was the development of a mine-specific Water Operational and Closure Plan (WO&CP). A WO&CP was developed for each of the 5 operating mines and consists of two components. The first was a status quo assessment of the mine’s mine water management capacity and the second component was a water management action plan that provided the mine with a practical and scientifically motivated road map and plan that the mine should implement:

- To conduct current and future business in such a way that Sasol Mining stays profitable, complies to legislation, is sustainable over the long term, manages and reduces long-term water risks and liabilities, and obtain closure certificates under DME and DWAF legislation.
- To document and demonstrate that all reasonable measures and/or interventions were applied during operation and decommissioning phases to reduce residual water impacts after closure.

The Phase 3 Work Packages consisted of nine technical studies, including:

- Continuation of the rainfall monitoring and analyses programme and incorporation of radar imaging technology
- Refinement and de-bugging of the UWMS and implementation and training at the mines
- Development of a geochemical salt mass balance as an add-on for the UWMS program
- Development of recharge potential (“water make grids”) maps for all operating mines
- Development of decant models based on the Phase 2 generic decant model for all operating mines
- Gap analyses and review of current monitoring systems and programs
- A plan for the integration of water management tools (UWMS, geochemistry add-on, recharge potential grids, surface water models) with existing mine planning tools (X-PAC, XERAS, Microstation, MINEX)
- A geochemical sampling program of coal and overburden materials at existing mines
- Electronic version of the existing Best Practice Guidelines
- Development of Water Operational and Closure Plans for the existing mines

Various supporting research projects related to mine water management have been conducted by the Water Research Commission and Coaltech during this period in which Sasol Mining developed the stated mine water management capacity. The finding of this research was incorporated into the Sasol knowledge base by the specialist working on the capacity development.

RESULTANT CHANGES IN BEHAVIOUR AND MINE WATER MANAGEMENT PRACTICES

The Capacity Development Program at Sasol Mining has resulted in a number of changes in operating practices and strategic decision making regarding mine water. The following examples of key decisions and changes in practice based on the results of the Capacity Development Program are highlighted:

RESCHEDULING OF CURRENT MINES

The better understanding of the flow mechanisms associated with underground water balances as well as the creation of software tools (UWMS) allowed the mine planners to adjust mine plans and schedules in order to affect a balance between the creation of storage space for underground water during the operational phase and the volume of water created by advancing mining fronts.

The threat of disruptive flooding incidents during the wet seasons combined with the ability to predict mine water-make as a function of mine scheduling allowed for the optimisation of underground storage through the construction of appropriate water storage compartments. Planning to maintain a negative water balance during the operational phase has become acceptable practice and annual water budgets are part of the planning and budgeting process.

Standard Operating Procedures and civil engineering design of operational compartment seals were developed during this process and are now part of the standard operational and mine planning process.

CALCULATION OF COMPLEX LEVEL WATER BALANCES

Forecasting of the combined effect that current and planned future mines of the Sasol Secunda Mining Complex would have on the Upper Olifants River and Waterval River Catchments was made possible by the capacity development that has taken place. This information has been used in a Strategic Environmental Assessment conducted by the CSIR for Sasol and formed the basis for various strategic decisions regarding capital expenditure for water treatment plants.

The effect that the Total Extraction mining method has on the Complex water balances was evaluated in order to compare the cost of post-closure water management with the loss of reserves if Total Extraction mining was not applied. This comparison highlighted the fact that final decant volumes and qualities can significantly be affected by the way the mine is designed/scheduled and operated and that consideration of the Best Practice Guidelines generated during the Capacity Development Program can significantly reduce post-closure water liabilities and risks.

DESIGNING NEW MINES

Perhaps the best example of changed behaviour is the recently completed design phase of the new mine that will replace one of the existing mines that is approaching the end of its allotted coal reserves. By making use of the recharge potential grids, mine water balances and understanding, geological structures and the groundwater inflow associated with these structures, mine design optimisation was able to include mine water related criteria as well as logistical and financial considerations.

Based on the water make grids, a selection of approximately 25% of the coal reserves in the dryer areas could be mined using high extraction methods while limiting the water make to 8% of Mean Annual Precipitation (MAP) over the life of the project. The restriction of high extraction mining to the dryer areas and judicious scheduling of wetter areas to be mined as late as possible in the expected life of mine, will result in the mine taking 300 years to fill after mining has been completed. Furthermore, it is expected that by limiting the water make to 8% of MAP, decant of water to the surface is unlikely to occur. The resultant water management plan was documented in the EMPR and accepted by the relevant authorities.

RE-USE AND RE-CYCLING OF WASTE STREAMS

The ability to calculate first order volumes and qualities for mines and the mining complex during the operational and closure phases as a result of the capacity building has led to the identification of various initiatives and internal research projects. One specific initiative that is worth mentioning is the establishment of a Water Steering Group consisting of personal from both Sasol Mining and Sasol Synthetic Fuels. This group is mandated to evaluate better ways of integrating water and waste streams between the business entities in order to reduce waste and optimise re-use of waste streams. Various waste stream sub-groups exist that look at specific issues surrounding a particular waste stream. These groups also identify research requirements for the evaluation of new innovative ideas about re-use and re-cycling. Sasol Research and Development (SASTECH) is currently involved in approximately 9 research projects aimed at evaluating specific issues surrounding the re-use of certain waste streams. Of particular interest is the use of mine water for cooling purposes, the use of ash as a sink for mine water salts and treatment brines, the use of ash as a source of alkalinity in mine water treatment, ash (and brine) backfilling in underground mines, and potential irrigation using gypsum-rich mine water.

EVALUATION OF IMPACTS ON THE RECEIVING SURFACE WATER ENVIRONMENT

A probabilistically based surface water model was developed for the Sasol Secunda operations up to monitoring point RESM 01, which is seen as the final control point for the Sasol operations in the Water al River Catchment. The model is calibrated by a network of surface water monitoring points in the upslope catchment and can calculate and predict water qualities and salt load impacts on the receiving surface water environment. The model has also been used to prioritise mitigation measures by being able to calculate specific waste loads associated with 37 facilities constituting the Sasol Secunda operations. The model is currently being used to evaluate various waste load water management options at a strategic level and includes mine water management strategies.

THE WAY FORWARD

As illustrated by this brief account of the history of the development of water management capacity at the Secunda Mines, the development has now progressed to a point of complexity that requires a structured approach to identify the most appropriate way forward. Although implementation of the existing knowledge base and water management capacity at the mines is the current focus of development, a more structured methodology is required.

When reviewing the WRC and Coaltech supported research, much attention has been given to developing end-of-pipe treatment processes and assessing inter-mine flow and various other essential yet fragmented issues. A project proposal recently solicited by the WRC to assess the extent of the long term impact that coal mining will have in both the Upper Vaal and Upper Olifants catchments indicates a shift towards addressing the more strategic issues. The completion of this project will for the first time provide an independent and authoritative view on the impact that the coal mining industry will have on these catchments, some 50 years into the future, when all the known coal reserves will either be exploited or severely depleted.

Having this end-game view in mind is essential to assessing the effectiveness of our current knowledge, competence and water management strategies, all of which contribute towards resolving industry water-environment legacy problems and to developing sustainable new mine designs and operating practices. Sasol Mining has started identifying further development and research projects with long term sustainability as a goal and in the full knowledge of the contribution made by the development work that has been done over the past ten or more years.

An inventory of the current knowledge, competence and successful strategies and practices at the mines was established with a view to defining what the state of our ability to work towards sustainable mining is. To guide the selection of future development projects and research initiatives, a cascade of clearly defined objectives that will lead towards more sustainable mining practices at current mines and to more sustainable design of future mines has been generated as a management decision support tool.

This shift in our paradigm from short and medium term crisis management and problem solving towards an integrated sustainability-directed approach to project and research identification will not come about by chance. Deliberate steps need to be taken to develop a structured approach to deliver sustainable mine operation and closure. Knowledge creation and learning needs to move forward in a manner that will empower mine operators to take a strategic stance on the issue of mine water management that is economically, environmentally and socially responsible.

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