A PRELIMINARY MANUAL FOR THE DESIGN OF COAL MINE PITLAKES AS AN ENVIRONMENTALLY STABLE CLOSURE OPTION IN SOUTH AFRICAN MINES

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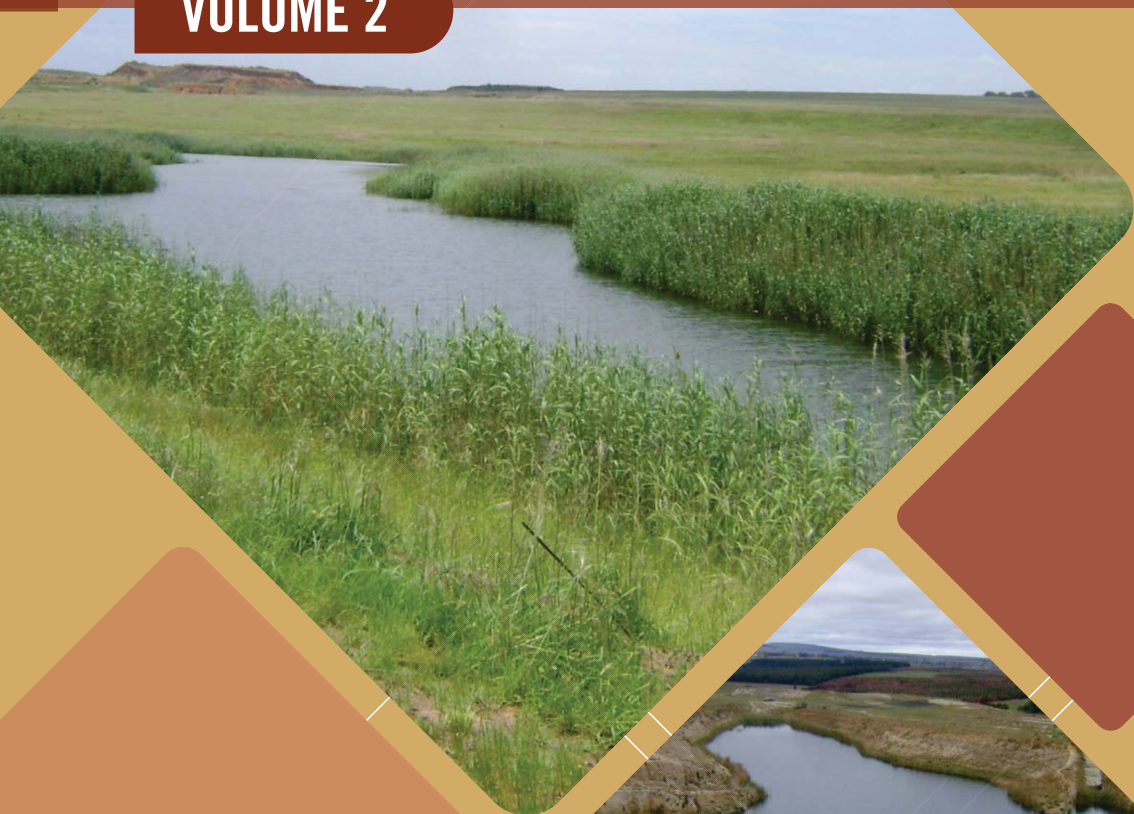
VOLUME 2



WATER RESEARCH COMMISSION

TT 797/2/19

A PRELIMINARY MANUAL FOR THE DESIGN OF COAL MINE PITLAKES AS AN ENVIRONMENTALLY STABLE CLOSURE OPTION IN SOUTH AFRICAN MINES

Report to the Water Research Commission

by

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WRC Report No. TT 797/2/19
ISBN 978-0-6392-0075-0

August 2019

Obtainable from
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This preliminary manual was compiled as part of a WRC-funded research project ans should be read as part of WRC report 2577/1/19: An Investigation to Determine if South African Coal Mine Pitlakes are a Viable Closure Option.

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INTRODUCTION

South Africa has been mining coal since the early 1800s, initially by conventional underground methods, but since 1950 the majority of the coal production has been from open cast mines. Coal is the major component of the South African Power supply network and this is predicted to continue into the latter half of the 21st century. Open cast coal mines generally leave a final void because of the mining method, insufficient overburden to fill the voids created by removal of the coal and /or to manage water. Once mining operations cease, these voids fill with water forming a lake which is generally referred to as a "pitlake". The author has estimated that there are over 200 pitlakes in the three major South African coal fields namely the Mpumalanga/Witbank/Highveld, KwaZulu-Natal and Waterberg areas. The research study evaluates the environmental sustainability of using pitlakes as a closure option for old and proposed coal mines in South Africa. The current South African mining and environmental legislation states that all pitlakes should be backfilled for the mine to achieve mine closure.

The major factors which determining environmental sustainability of pitlakes are the water balance and water quality. Positive water balances result in discharge onto surface. The water quality of a pitlake determines the future use and the environmental risk. Pitlake water quality varies depending on the geology, mining method and catchment characteristics. In general, pitlake water quality may not comply with legislated catchment water quality standards.

This investigation concentrated on the two major drivers of pitlake sustainability (quantity and quality), whilst investigating four different pitlakes; The pitlakes were selected on the basis that they are representative of the major South African coal fields considering variances in geology, climatic conditions and mining methods.

Sufficient data was collected in the study to allow for the development of a guideline for the design of coal mine pitlakes in the South African coal fields. This preliminary design manual considered the water balances of the pitlakes and the biological and chemical process that drive the water quality of pitlakes. The aim of this manual is to provide guidelines for the design of coal mine pitlakes for the pitlake to be a sustainable closure option.

Summary of the key findings

Detailed below is a summary of the major finding of the study and the reader is referred to WRC report 2577/1/19 for more details.

The factors affecting pitlake water balances (and as a result the variation in water levels) are groundwater, direct rainfall, runoff; while the losses from the pitlakes are evaporation, surface discharge and flow into the surrounding aquifer. The water balances of each of the pitlakes were evaluated to determine the major inputs and losses. The major input was groundwater, either from the aquifer or backfilled material, and the major loss was evaporation. Pitlake morphology, volumes and surface area are the major design considerations to prevent discharge of pitlake water into catchment.

The water quality in a pitlake determines the long-term ecological sustainability of pitlakes. The inorganic chemistry study concentrated on the water quality and vertical stratification. The in-situ parameters that were measured were pH, temperature, dissolves oxygen and the redox potential of each of the pitlakes. The organic study determined the phytoplankton, chlorophyll-a and the microbiology of the pitlakes. Additional research is required into the ecology to fully understand the evolution of the pitlake (Blanchette and Lund, 2016).

The conclusion of this study is that pitlakes can be environmentally sustainable if designed correctly. The organic and inorganic water quality in the pitlakes studied showed that the pitlakes are alkaline and have elevated total dissolved solid contents (mainly calcium sulphate) when compared to the natural surface and groundwater in the catchment. Pitlakes can support life in terms of chlorophyll-a, phytoplankton and microbiology (bacteria). The study did not investigate the biota or vegetation that the pitlake supported.

The surface area of a pitlake is vitally important to maximise evaporation which directly affects the water balance. In addition, surface runoff should be controlled to avoid excess runoff into the pitlake that may lead to a temporary positive water balance and uncontrolled discharge into the catchment. Should the pitlake be suitably designed, it forms a *"terminal pitlake"* which is a water sink and prevents uncontrolled discharge.

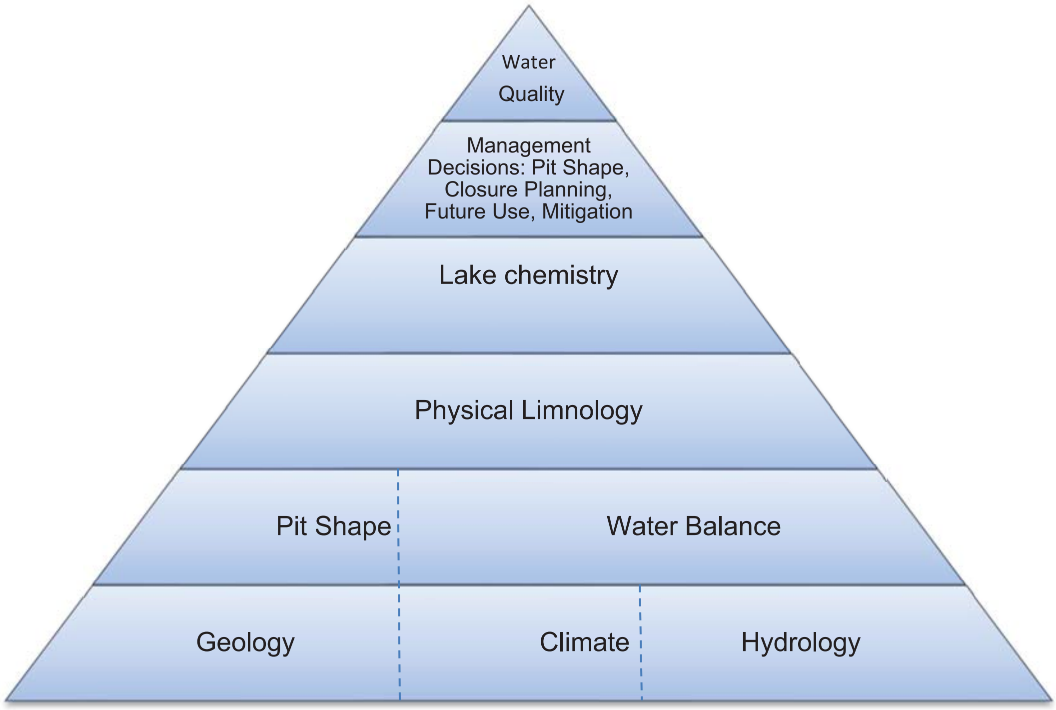
A fundamental change in the thinking and the South African legislative requirement is required to view pitlakes as an environmentally sustainable solution, to prevent uncontrolled discharge from open cast mining operations and to avoid the expense of ongoing water treatment. Correctly designed pitlakes offer an environmentally sustainable option for open cast coal mine closure in South Africa.

Design Considerations

This manual only deals with "terminal sink "and does not consider "flow through" pitlakes.

There are several fundamental considerations in the design of a terminal sink pitlake. These design concepts should be incorporated into mine plan and then developed into the mine closure plan and implemented during the last stages of mining while the earth moving equipment is still active on site.

The theory of pitlakes is based on research completed by Castendyk et al. (2009) and is shown in the figure below. Conceptual relationship between the principal factors that affect pitlake water quality, where different elements ultimately contribute to the pitlake evolutions and their sustainability.



Conceptual relationship between the principal factors that affect pitlake water quality (after Castendyk and Eary, 2009)

The classification of pitlakes is primarily based on their interaction with the hydrology of the pitlake as described by Niccoli (2009):

- Flow-through pitlakes – groundwater and/or surface water flows into and out of the pitlake due to rainfall rates that exceed evaporation rates, and where the net water balance surrounding the pit is positive.
- Terminal sinks – Groundwater flows into the pit and the only outflow is evaporation. Accordingly, the net water balance surrounding the pit is negative.

The aim of the design of South African Pitlakes is that the pitlake is a terminal sink and prevents discharge onto surface under normal climatic condition. This manual does not consider flow through pitlakes as no flow through pitlakes were investigated as part of the study. In addition, the aim of the design manual is the ensure that the water quality in the pitlake is able to support an ecosystem no matter if it does not comply with catchment water quality standards. This maybe a licensing issue in terms of the National Water Act 1998.

Factors to consider in Pitlake water balances

The water balances are calculated based on a generalized mathematical expression, described by Gammons et al. (2009):

$$\Delta S = (P + SWin + GWin) - (E + (T) + SWout + GWout)$$

where

ΔS is change in storage which is the volume of water in the lake,

P is the precipitation falling onto the pitlake,

SWin is the sum of any surface water inputs which includes runoff and diverted streams,

GWin is groundwater entering the lake,

E is the evaporation from the lake,

T is plant transpiration (which is often negligible;),

SWout is surface water existing in the pitlake and includes pumpage,

GWout is the groundwater leaving the pitlake.

Discussion on the water balance components

ΔS; the aim is to maintain the pitlake level below the point of discharge on surface. In addition, the freeboard in the pitlake must be sufficient to allow for seasonal fluctuations in pitlake levels. As a tool a dynamic pitlake model should be used to determine the pitlake water balance and the potential variations in pitlake water levels.

P; Precipitation. In South Africa evaporation exceeds precipitation by a factor of 2-5 depending on the geographical location. Precipitation intensity and annual variations are critical in calculating pitlake water balances.

SWin; is the runoff into the pitlake from the catchment. This can be from natural catchment runoff or from the sidewalls of the pitlake. The aim is to keep runoff from the catchment into the pitlake to an absolute minimum to prevent a net positive water balance and discharge on surface. Another principal that should be incorporated into the surface water balance is the separation of clean and dirty water, where dirty water can be diverted into the pitlake (should the water balance still be negative) and the clean water into the catchment.

GWin; Groundwater inflow into the pitlake is usually greatest when mining ceased and the groundwater gradients into the pitlake are steep. As the pitlake levels rebound the net contribution to the pitlake water balance decreases. Where there is hydraulic connection between the pitlake, backfilled spoils and underground operation the net contribution of the historical mine areas should be assessed both in terms of volumes and quality (salt load contribution to the pitlake). In open cast operation the contribution to the pitlake water balance from recharge to the open cast spoils is a major consideration in terms of net inflow into the pitlake and the impact on the pitlake water quality.

E; Evaporation is the fundamental parameter that enables pitlake in South Africa to be sustainable. As a result, the area of the pitlake and the corresponding evaporation must exceed the sum of all the potential inflow. In other words, the greater the sum of the inflows the greater the surface area of the pitlake to allow for enough evaporation. Another consideration is that an excessive negative water balance will lead to an increase in salinity of the pitlake.

T; transpiration in South African pitlake is generally very low due to the limited vegetation in the pitlake. However potential transpiration must be included into the calculation of the pitlake water balance. This is more applicable to shallow pitlake that can support vegetated fringes.

SWout; Discharge from the pitlake must be avoided as the discharge water will not comply with catchment water quality standards. As a result the aim of the pitlake design is to eliminate SWout under natural climatic conditions and for return periods of less than 1:20 years.

GWout; Groundwater out is generally limited in South African pitlakes as pitlake tend to rebound to the near pre-mining groundwater levels. Groundwater gradients tend to be towards the pitlake if the lake is a terminal sink. Outflow into the aquifer usually only occurs during periods of excess inflow into the pitlake and an associated rise in the pitlake level above regional groundwater level. This may occur for limited periods.

The water balance of pitlakes is important, as it determines if the pitlake will discharge water into the environment and impact on communities and downstream water courses. Water balances in mines comprise an important role in mine planning and management, where calculations and decisions on best practice are made based on the prevailing climatic and hydrological/ hydrogeological conditions of the mine. If it is decided that a terminal pitlake is the best option for a mine closure, it should be incorporated into the initial mine plan.

Factors Impacting on Pitlake water quality

One of the most important factors to consider in the design of a pitlake is the water quality and if it will be a sustainable ecosystem. A major task is to predict the final pitlake water quality and how this water quality may evolve over time. The water quality must be assessed in determining the environmental sustainability of the pitlake.

During this study we did not find any final pitlakes that had really poor water quality. The research did not study any acid coal pitlakes. The pitlakes studied had a neutral to slightly alkaline pH and a total dissolve solid content varying from 1000 to 4000 mg/l mostly sodium bicarbonate in nature. Research by Annandale et al. (2007) has shown that the water is acceptable for agricultural irrigation.

One of the biggest impacts on water quality and the water balance of the pitlake is the level of rehabilitation on previously opencast material. The surface of opencast spoils should be rehabilitated to allow vegetation growth and normal soil forming process. The establishment of soil and vegetation reduces recharge to the spoils and as a result the salt load into the pitlake (Coleman et al., 2011).

Sulphide rich overburden above the coal seam has the potential to generate poor quality leachate. Also discard from washing plants and slimes also has the potential of generating low pH and poor-quality leachate. As a result, any potentially contaminating material must be place below the rebound water level. Climate change factors should be incorporated into the water balance calculations.

In general, shallow pitlake are more subject to wind which leads to aeration and introduction of oxygen into the pitlake. This has the added advantage of oxidising and the precipitation of metals. An additional advantage of shallow pitlakes is the increase in surface area and the corresponding evaporation.

Conclusions

Correctly designed terminal sink pitlakes are a sustainable mine closure option in South Africa. Backfilling of pitlakes removes one of the major benefits of a pitlake, which is evaporation, and creates the potential of uncontrolled surface discharge and the associated treatment.

This brief manual is aimed at highlighting some critical factors that have to be taken into consideration in designing environmentally sustainable pitlakes. The correct scientific data must be collected and applied to achieve the desired results which is an environmentally sustainable pitlake.

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