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Rational decision-making in the sustainable configuration of tailings

A system is described in which different environmental impacts and engineering design costs are integrated. It applies integrated environmental planning and design principles to the design of tailings impoundments, and the result is an environmental impact and engineering cost model for the configuration of impoundments. In this case, a theoretical ecological and sustainable philosophical approach was used to evaluate, assess and analyse environmental impacts and formulate solutions for the post-closure land use of tailings impoundments

MINING OF South Africa's gold, platinum and base metal resources has given rise to hundreds of mine residue deposits (MRDs) of which the footprints cover large areas of land.

Metalliferous mines produce a substantial volume of fine-grained waste and it is estimated that between 11 500 and 12 000 ha of land is sterilised by approximately 150 MRDs within Gauteng province alone (figure 1). Mine residue can contain sulphide minerals, which upon weathering give rise to a range of potential pollutants. Where there is insufficient neutralising potential in the mine residue, acid mine drainage (AMD) occurs with its associated low pH values, high salt loads, and high concentrations of metals.

Radionuclides are also found in some drainage associated with MRDs. Seepage to groundwater and discharge to surface water can give rise to water pollution over large tracts of land. MRDs are often physically unstable and susceptible to erosion, thus giving rise to long-term wind and water-borne pollution. The quantitative prediction of these impacts is difficult, and they are costly to manage and mitigate.

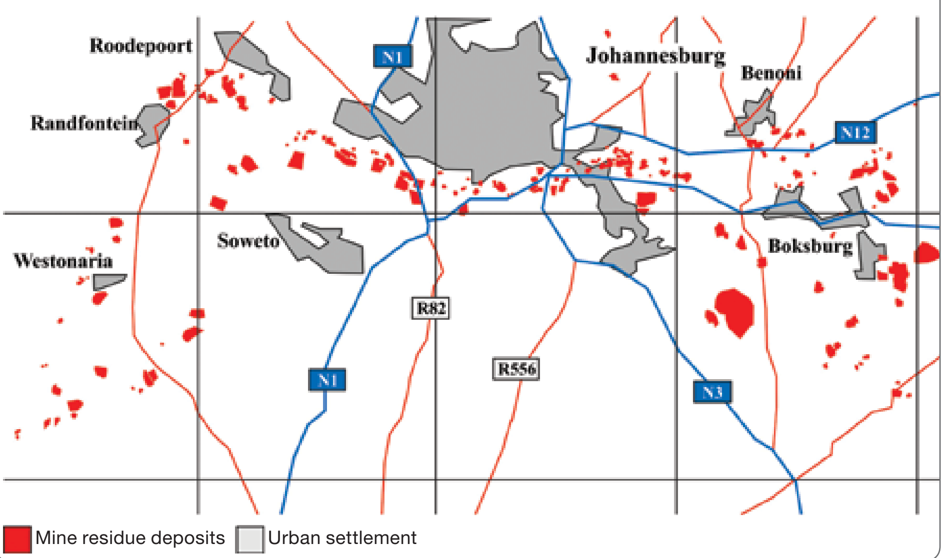
Concepts of sustainable development necessitate even more positive outcomes with regard to the post-closure state of a scheme. Post-closure land use and the cumulative impacts of a tailings impoundment have become increasingly important. Figure 2 illustrates the general perception that the cost of environmental protection works has, over the years, become a much larger proportion of the total tailings impoundment construction costs and suggests that this is increasing for various reasons:

- There is a growing expectation for sustainable development
- Environmental legislation is becoming more stringent
- Stakeholders are becoming more aware of potential short-term and long-term environmental hazards

The impacts associated with MRDs – particularly in the long term and after closure – have given rise to an increasingly complex regulatory regime. It is difficult to obtain approval for upgrading old facilities, for developing new facilities, and for closing plans, because there is no suitable framework within which to make decisions. Since efficient development of the South African mining sector is essential, it is necessary to develop a coherent system to facilitate transparent and effective decision-making while maintaining a balance, with an acceptable level of environmental risk.

Environmental impacts and costs should be managed, so that reasonable objectives can be attained.

Figure 1 Footprints of mine residue deposits in and around Gauteng province



SUSTAINABLE DEVELOPMENT

Sustainable development applied to tailings impoundments includes rehabilitation with the aim of returning the land to some sort of agreeable land use and eliminating or reducing adverse environmental impacts to a long-term acceptable condition.

Land development pressures necessitate a paradigm shift in dealing with the problem and what may have been standard practice some years ago is no longer acceptable. This can probably be best illustrated with a few examples.

- New residential developments are constructed on vacant land in-between and

impoundments

in some instances adjacent to old MRDs (figure 3, photograph 1).

- The Top Star drive-in, south of the Johannesburg CBD, is located on an MRD and demonstrates how something which would otherwise have laid barren after closure are used for something quite novel (figure 3, photograph 2).
- The Geraldton tailings impoundment rehabilitation project is a prime example of how mine residue can be used to create a sculptural landform within a landscape (figure 3, photographs 3 and 4). This impoundment is located at the main entrance to Geraldton, Ontario, Canada, and lies 320 km northeast of Thunderbay. Approximately 14 Mt gold tailings was deposited over 70 ha at an average height of 16 m. It was decided, as part of an economic redevelopment initiative, to reshape the abandoned impoundment and improve its appearance. The landform is not only sculptural but provides for activities such as walking, mountain biking, bird watching and snow boarding.

INTEGRATING ENVIRONMENTAL IMPACTS AND ENGINEERING DESIGN

The system developed is innovative because

Figure 2 Schematic illustration of the perceived increase in tailings impoundment cost over time

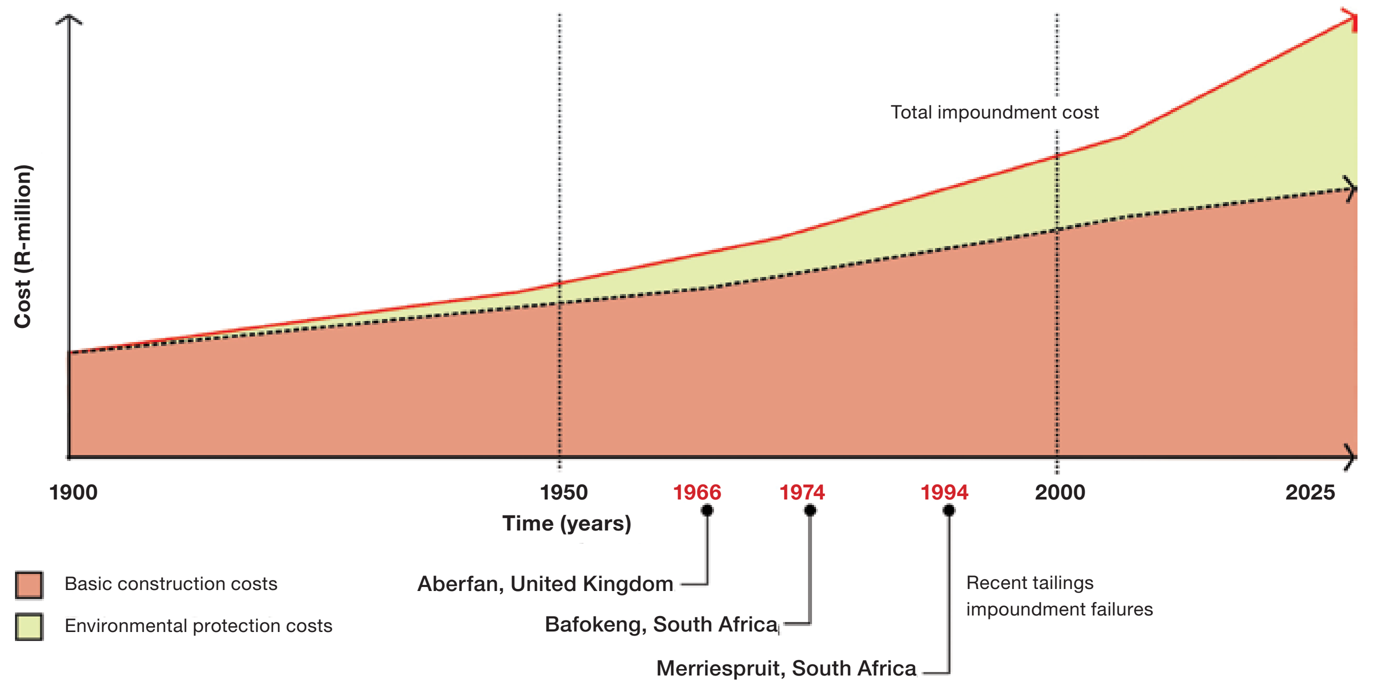


Figure 3 Land development pressures often lead to the rehabilitation of existing tailings impoundments to create some sort of appropriate landform while also addressing significant environmental impacts

▶ ***1*** *New residential development in Krugersdorp, Gauteng, adjacent to an existing un-rehabilitated tailings impoundment.* ***2*** *The Top Star drive-in is located on an old mine residue deposit south of the Johannesburg CBD.* ***3 and 4*** *The McLeod high tailings impoundment to the entrance of Geraldton, Ontario, Canada, has been reshaped to create an environmentally stable sculptural landscape*
(photographs courtesy of Martha Swartz Partners)

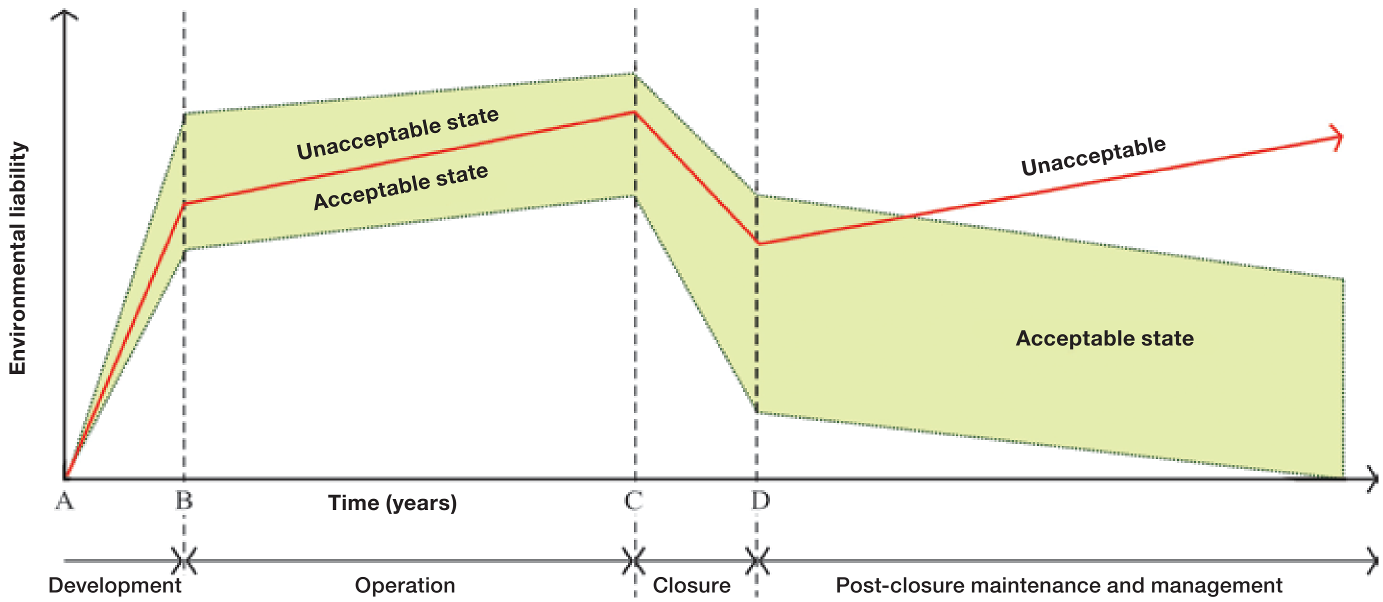
it envisages tailings impoundment design from the view of landscape architecture and introduces the concept of visual impacts in a novel way. It includes a study to gain knowledge about the visual perception of tailings impoundments which aims to determine critical threshold distances of detection and recognition of a tailings impoundment with different geometric alterations and surface covers. The effectiveness of mitigation is measured against the capability to 'camouflage' the tailings impoundment with its environment and to reduce visual impacts.

Three surface covers are photo-realistically simulated in figure 5 and indicate the difference in visual perception when altering the surface cover. The scenario with the diversity of vegetation species (bottom) can easily be mistaken for a natural landform, and it is assumed that alterations to the overall geometry of the tailings impoundment will contribute to the camouflaging effect.

The system models key environmental impacts and engineering costs throughout the life cycle of a tailings impoundment such that the design can be optimised *ab initio* with respect to the environmental impacts and costs (figure 4).

This conceptual model demonstrates the environmental liability for the owner at any stage. The solid line represents the environmental liability of an impoundment configuration and may be defined as unacceptable as it will require ongoing

Figure 4 Conceptual environmental liability graph over the life of an impoundment. The shaded area indicates a preferred acceptable state over time



maintenance, the post-closure land use is not clearly defined, and the impoundment is aesthetically unacceptable.

The environmental impact and engineering cost model can be used to:

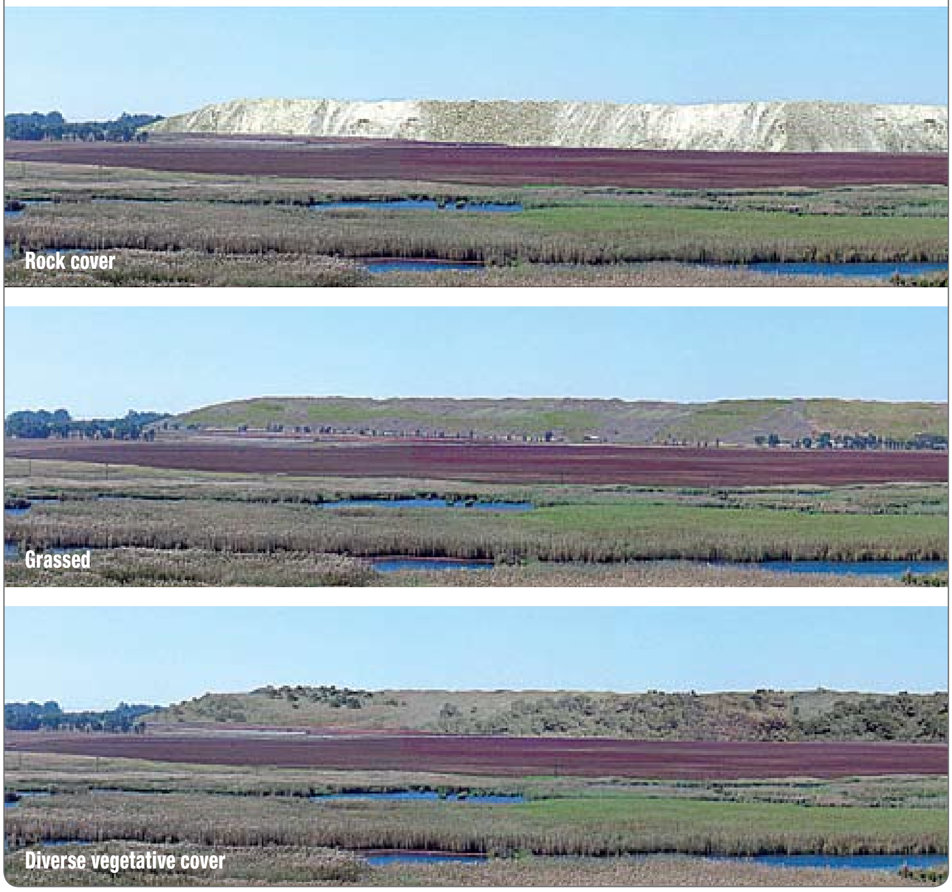
- Inform the planning process during the conceptualisation of feasible alternatives
- Assist with decision-making
- Provide a platform for constructive discussion with relevant authorities
- Facilitate transparent liaison with stakeholders

Regulators, proponents, and consultants can use the system to better understand what the important implications are of flattening tailings impoundment embankment side slopes and changing covers.

Through a process of elimination, various key environmental aspects that influence tailings impoundment design are integrated with the engineering costs, namely visual aspects, air quality, and water (figure 6).

The view was taken that initially only these aspects will be included with the aim of creating a robust system demonstrating its efficacy. It was also realised that some of the input parameters in the system would not be definitive and that applying conservative value judgements may be required.

Figure 5 Visual simulations of different surface covers



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