Tailings Facility Management: Modelling Tools for Life of Mine

Roald Strand[1], Muhammad Parker[2], Jaco Grobler[2], Nigel Moon[2]

[1]Golder, Australia, University of Queensland, rstrand@golder.com

[2]Golder, Australia; mparker@golder.com; jgrobler@golder.com, nmoon@golder.com

Abstract

Tailings facility water balance models have been used historically to simulate major hydrologic drivers on tailings facilities (Strand and Usher 2014). Recently, we have addressed growing regulatory oversight by providing tools to improve understanding of tailings storage facility (TSF) in context of environmental compliance (Moon et al. 2018).

To address our clients concerns with environmental compliance for TSF's, we have developed an integrated approach to service a growing field with customised simulation tools. Specifically, GoldSim has been outfitted with integrated climatic drivers and geochemical drivers to account for unplanned variance in expected responses (Strand et al. 2017). Major considerations include climate change, climatic influences such as evaporation and dilution, geochemical stability of tailings and consideration of such human influences as pump failure or dosing pond dredging.

End users and operators have used simulation systems to manage tailings facilities with higher resiliency to climatic effects, plan water storage and use, plan water treatment capacity, meet water quality compliance at mine lease boundaries, assess environmental impacts of specific projects such as mine waste placement strategies and plan closure (Strand et al. 2010, Usher et al. 2010, Strand and Usher 2014, Moon et al. 2018).

We explore four different examples and highlight how the models aided in solving complex questions, and added value or avoided unnecessary expenditure.

Keywords: Tailings Facility Modelling, Water Balance Modelling, Modelling, Water Quality Modelling

Introduction

Water balance models are required for a variety of regulatory purposes in Australia (DEHP 2012, DAWE 2020, DNRM 2018) and are regularly employed to predict the response of a system either in preparation of the wet season or during the wet season. Water quality models are frequently employed to produce conservative estimates of mass fluxes in association with water balances.

In Australia, with elevated evaporation rates and rainfall occurring predominantly during the wet season, there are other factors to consider, such as solubility constraints.

The authors have developed models to capture critical drivers on system stability and instability while accounting for nuance in operational strategy for TSF systems in Australia and the Americas. The examples indicate that TSF modelling may help operators understand and plan for the seasonal variance – whether that occurs via rainfall, water storage or salinity in mill feeds. We have provided standard water-balances and upgraded water quality models for tailings facilities to enhance understanding of constraints and operational response to human and environmental drivers in context of water and water quality.

Example 1

Location: Western Australia
Mine name: (confidential)
Facility: Tailings facility
Associated infrastructure: Mill, reticulation, pumps required for river abstraction

Description:

A TSF water balance model was built for a Goldmine in Western Australia. The client was concerned about the influences of large tailings beach on the TSF water balance; so,

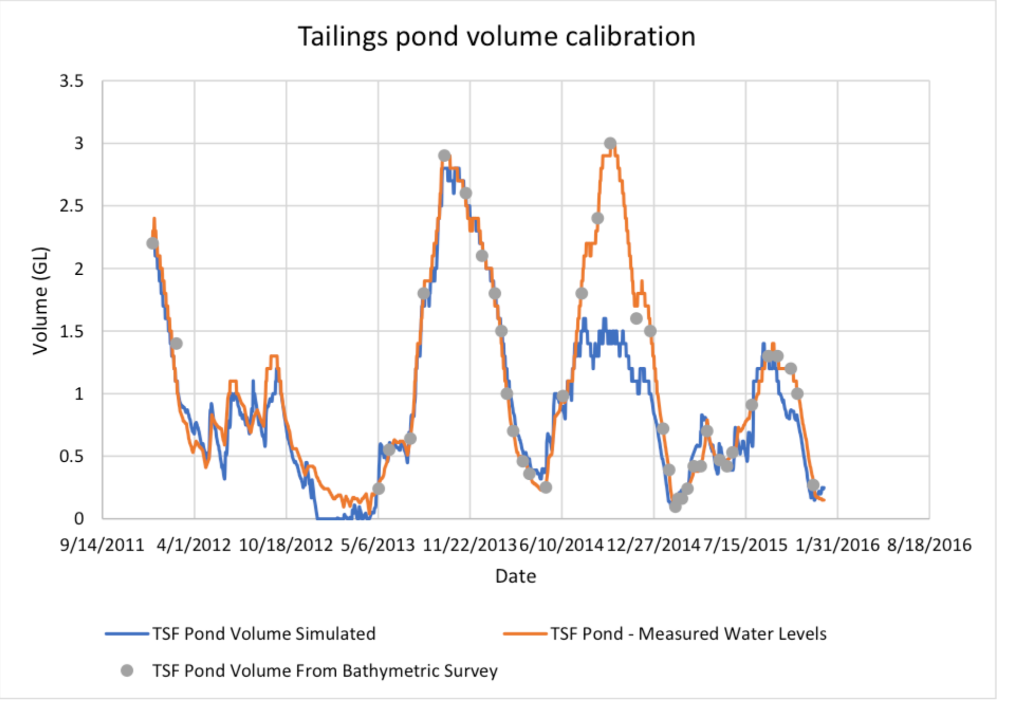

Figure 1 *Comparison of Observed and Modelled Storage Volumes for TSF.*

the model was outfitted with algorithms to predict runoff response based on tailings (beach) moisture and deposition (above the water surface).

Water volume in the TSF was calculated using measured water level elevation data and storage and bed elevations based on the bathymetric surveys. These are shown in Figure 1. These two sets of data were together utilised to derive storage volumes between the bathymetric survey dates.

The calibration of the TSF water balance was achieved by adjusting runoff coefficients associated with the estimated moisture in the tailings beach. The results of this calibration are shown in Figure 1.

Based on a comparison of the simulated and historic storage volumes (Figure 1) the model is able to simulate the general trends and changes in the TSF storage volume over time.

The problem which was solved was a water deficit. After calibration, the model was used to identify potential options to increase water holdings; TSF return water volumes for varying climate conditions including climate change to assess the river abstraction volumes and pumping rates (O'Hara et al. 2012). TSF pond water storage within the extent of the TSF liner has been maintained with the aid of the model.

Example 2

Location: Western Australia
Mine name: (confidential)
Facility: TSF

Description:

The Tailings pond (TSF) model was built to operate at a daily time step and is used to predict the water storage volume of the tailings pond (and its occurrence) driven by probabilistically generated rainfall, evaporation and tailings slurry properties.

The conceptual water balance for the TSF pond is shown schematically in Figure 2. The volume of the tailings pond and associated water fluxes into and out of the pond are dependent on changing dynamics of the TSF top surface landform due to ongoing tailings deposition.

The sources of uncertainty of future TSF pond water volume relates to future rainfall

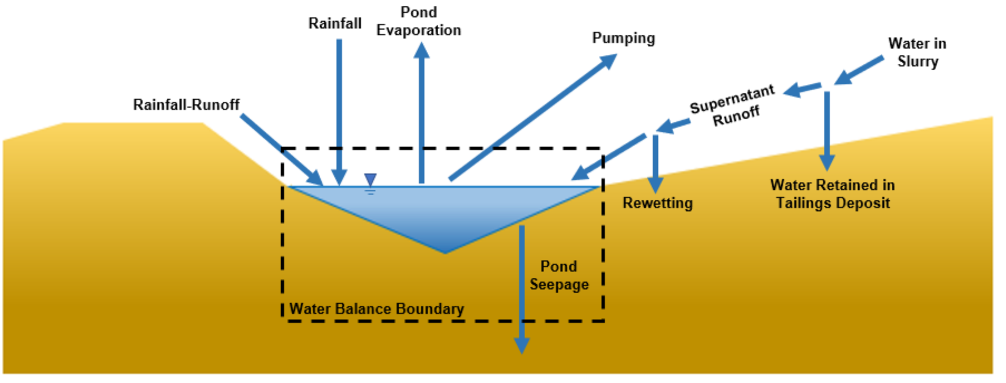

Figure 2 Conceptual TSF pond water balance model.

and evaporation. Probabilistically generated rainfall (and other input parameters) allows estimation of the water volume of the TSF pond and through Monte Carlo simulations, quantifies uncertainty associated with climatic effects.

Historic rainfall and evaporation data have been used to calibrate stochastic rainfall and evaporation generators based on the stochastic rainfall generator developed by the Catchment Research Centre (CRC) for Catchment Hydrology (Boughton 1999). These stochastic climate generators provide alternative estimates of rainfall and evaporation sequences with comparable probabilities of occurrence to each other and to the historic sequence.

The generators use transitional probability matrices to provide a representation of the historic probability of rainfall and evaporation rates occurring within defined ranges over the likely magnitude of extreme daily rainfall. This approach also takes into consideration the magnitude of the preceding day's rainfall and therefore preserves the historic daily rainfall patterns, as well as the frequency and magnitude of the daily rainfalls including the more extreme values. The generated rainfall and evaporation sequences also have comparable monthly, seasonal, and annual statistics to the historic period but with alternative, equally likely, daily patterns.

Simulating the water balance using many stochastic climate sequences (typically a minimum of 100) provides alternative, yet equally possible model outputs to provide an indication of the range and variability in likely fluxes and stores of the water balance. Running a larger number of model realisations will increase the likelihood of occurrence of more extreme climate patterns and events, such as prolonged periods of high or low rainfall years.

The client used the TSF water balance to provide an estimation of the return water pumping requirements to manage the pond size and avoid an inadvertent spill from the facility based on confidence limits which were calculated based on the Monte Carlo modelling approach.

Example 3

Location: Central Mexico
Mine name: (confidential)
Facility: Tailings Management Facility (TMF)

Description:

A mine in Central Mexico required modelling of the Tailings Management Facility (TMF) and water management structures as associated infrastructure.

The prefeasibility design for the TMF includes an unlined ring dike constructed of non-potentially acid generating (Non-PAG) waste rock with granular upstream filters and underdrains with central discharge of thickened tailings, alternated with placement of layers of potentially acid generating (PAG) waste rock. The design specifications include thickened tailings being pumped to the TMF.

A water balance model (WBM) was developed for the TMF. The objective of the modelling was to inform estimates of water fluxes and storage requirements over the construction and operations phase of the TMF.

The WBM operates at a daily time step and predicts volumes of the water and flow fluxes, and the associated variation and probabilities of occurrence driven by probabilistically generated rainfall adjusted to include various climate change parameters.

The TMF was separated into two zones to better simulate water fluxes during water balance modelling of:

- deposited tailings; defined as the area within the TMF containing tailings
- TMF dam and internal berms

Each modelled zone includes inflows and outflows; specific inflows and outflows can interact with both zones. For example, outflows from one zone may be inflows to the other. A schematic of the water fluxes within the TMF is shown in Figure 3. A list and a description of the water fluxes are provided below.

This model informed estimates of drainage from the TMF that would be available for re-use, accounting for climate change impacts. Runoff is very sensitive to variation in rainfall and evaporation and because runoff is the difference between precipitation and evaporation over the long term, the relative rate of change of each of these processes is critical in assessing whether water availability, and therefore water resources, will increase or decrease under various climate change scenarios.

Example 4

Location: Peruvian Andes
Mine name: (confidential)
Facility: tailings storage facility (TSF) and
Associated infrastructure: Mill, reticulation systems, seepage collection ponds

The tailings facility at this mine is a receptor for many flows from various parts of the mine. The mine was concerned the TSF was gaining water and wanted to investigate various mitigation options. Incidentally, a mill upgrade was also planned for around the same time as the base mitigation actions would be commissioned. Water balance modelling showed that the single most important water sink was the loss to pore space – a consideration that was not adequately accounted for in planning. As a result, a substantial reduction in water level was achieved in subsequent years – to the point that some mitigation measures were rolled back (Figure 4).

Original predictions for the throughput scale up were undertaken in 2013–2014, and the client had reservations about the

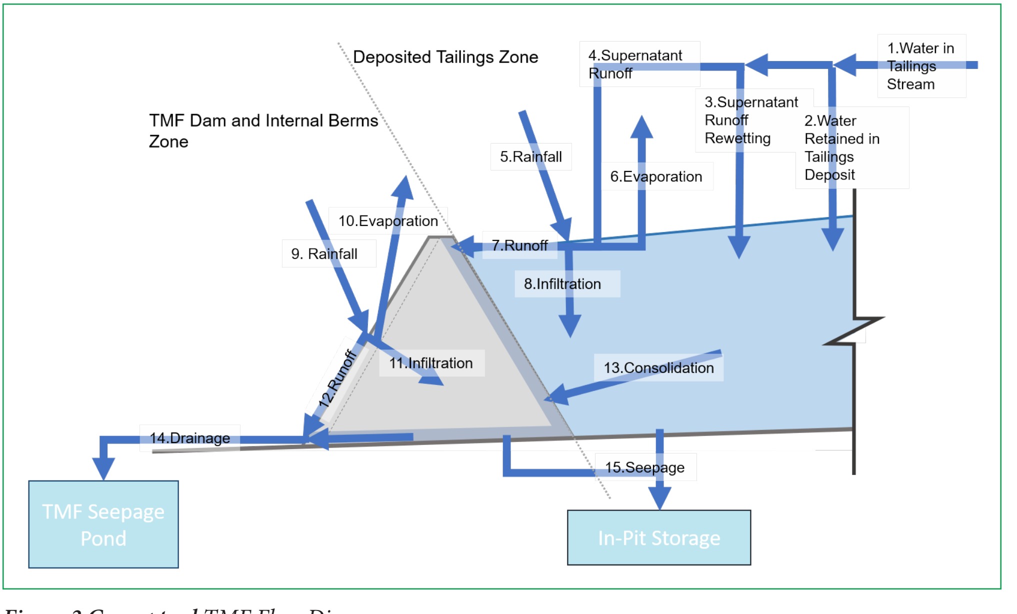

Figure 3 Conceptual TMF Flow Diagram.

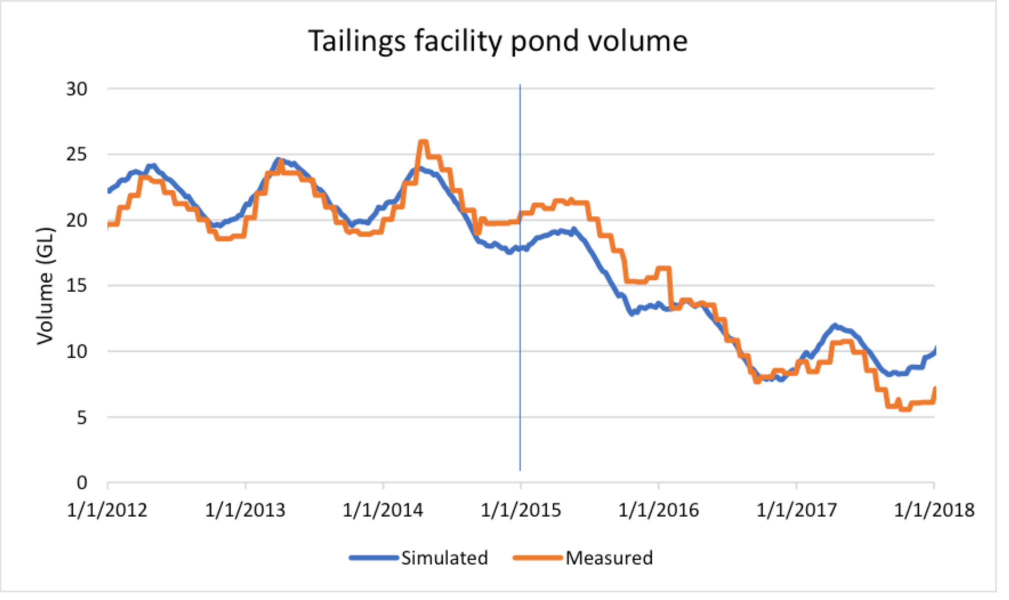

***Figure 4** Water volume response for throughput scale up (blue vertical line indicates commissioning date of increased throughput).*

predicted response. Other water balances were also employed which did not show this response.

The client invested further into this model, which was outfitted with water quality modelling and geochemical components to aid planning for reactive waste storage, water planning and seasonal discharge planning. Through systemic employment, the client was able to refine planning for reactive waste which reduced water quality influences upstream of compliance points and helped provide economic and environmental valuations for specific projects.

Conclusions

Water balance models are a useful and sometimes required investment. Calibrated models may yield benefits such as avoidance of overflows, effective management of seasonal flows or extreme events, effective management of climate change related factors, reduction of infrastructure expansion (and deferment of capital expenditures) or maintaining compliance with greater certainty.

Examples shown in this publication do not contain significant detail, but endeavour to show how various levels of detail may be used to obtain a relevant result. Various adaptations to water balances such as mass balances and even water quality equilibration systems may further increase utility and return on investment but may require specialist skillsets to build and employ.

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