A RISK BASED APPROACH TO WATER MANAGEMENT AT ROTOWARO OPEN CAST COAL MINE

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ABSTRACT

The Rotowaro Opencast Coal Mine, located near Huntly in the Waikato, is one of New Zealand's largest mining operations. Water management at the Rotowaro site is vital to the operation, the two key issues at the site being: water in the opencast mine pits interfering with coal winning operations; and the requirement to protect the local environment by the collection, conveyance and treatment of site water. Solid Energy uses a modelling and risk-based approach to plan the water management infrastructure at the site.

An innovative modelling approach has been applied that uses the US Environmental Protection Agency's Stormwater Management Model (SWMM) modelling package to simulate rainfall-runoff processes and the performance of the water management system (sumps, pumps, treatment). The model is run for a long-term rainfall record, which assesses the theoretical performance of the water management system for the rainfall events that have been experienced at the site over the last 25 years. The use of real rainfall records has been found to be important at Rotowaro as different parts of the water management system are sensitive to different types of events, e.g. sumps are at risk from short duration events, whereas pits are most at risk from long duration wet weather periods (not catered for by standard hydrological methods). The results are presented in a way that shows the risk of flooding of pits/sumps for different potential management options.

This methodology has been applied to the planning of water infrastructure to support the Awaroa 4 pit (maximum footprint 250 ha). Key considerations have been the provision of sufficient pumping capacity so that flooding of the pit from runoff is managed at a level that avoids unacceptable durations of interruption to coal winning, while at the same time designing sufficient storage outside the pit so that overflows to the local environment are eliminated.

KEYWORDS

Risk, Mining, Runoff, Pumping, Probability

PRESENTER PROFILES

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Kate is a water engineer at T&T. She has a wide range of experience in the water resources field including work on large infrastructure projects in New Zealand and internationally, such as the Northern Gateway Motorway Project, The Aniwhenua Reservoir Sedimentation Study and the Safety Audit of the Ambuklao and Binga Large Hydro Dams (Northern Luzon, Philippines). She became involved working as a consultant for the Rotowaro mine operation in 2008.

1 INTRODUCTION

1.1 ROTOWARO SITE

The Rotowaro Coalfield and Opencast Mine is owned by Solid Energy New Zealand Limited (Solid Energy) and is the second largest opencast coal mine in New Zealand. The mine is located 10 km west of Huntly township. It was first mined in 1915 as an underground mine after a branch railway and a bridge were constructed over the Waikato River. The present opencast mine opened in 1958.

The Rotowaro Coalfield and Opencast Mine covers approximately 2,440 ha in area. Figure 1 shows an aerial photograph of the site, with site features labelled. There are five open pits: Township; Awaroa 3; Awaroa 4; Waipuna and Boundary. Coal mining operations are currently proceeding in Township and Awaroa 4.

At Rotowaro, coal is mined from seams once the overburden (the soil and rock above the coal seam) has been removed by excavators and trucks. The overburden is placed in the pits where the coal has previously been mined and is then contoured to fit the surrounding topography. The areas are then replanted for future use as grazing pasture or for forestry, with native plantings adjacent to streams and in wetland or other designated areas.

The majority of Rotowaro coal goes by overland conveyor to Genesis Power's Huntly Power Station and by rail to New Zealand Steel's Glenbrook steel mill. The remainder of coal extracted from Rotowaro supplies the North Island industrial and home-heating markets. The annual production of around 1.5 - 1.9 million tonnes (mt) comes mainly from the many different coal seams in the Awaroa 4 pit. Up to approximately 7 mt of recoverable coal remains.

1.2 WATER MANAGEMENT SYSTEM

A potential environmental effect from the opencast mining is from land disturbing activities causing the erosion of soils and the water-borne transport of sediment into receiving environments. Therefore, the development and implementation of water management plans and systems for the dirty water runoff generated on site are integral parts of the ongoing mine planning and operation. Requirements for the control and treatment of dirty water are also part of the resource consents held by Solid Energy.

Rainfall runoff erodes soils from open faces of the mine or haul roads or overburden disposal areas. The eroded soils become suspended in the site "dirty" water. To ensure contaminated water from the site does not enter the natural waterways, the "dirty" water is collected, conveyed and treated at the Central Treatment Plant (CTP), prior to discharge into the Awaroa Stream. The CTP settles out suspended solids with chemical assistance from flocculation and coagulation agents. There is a second treatment plant

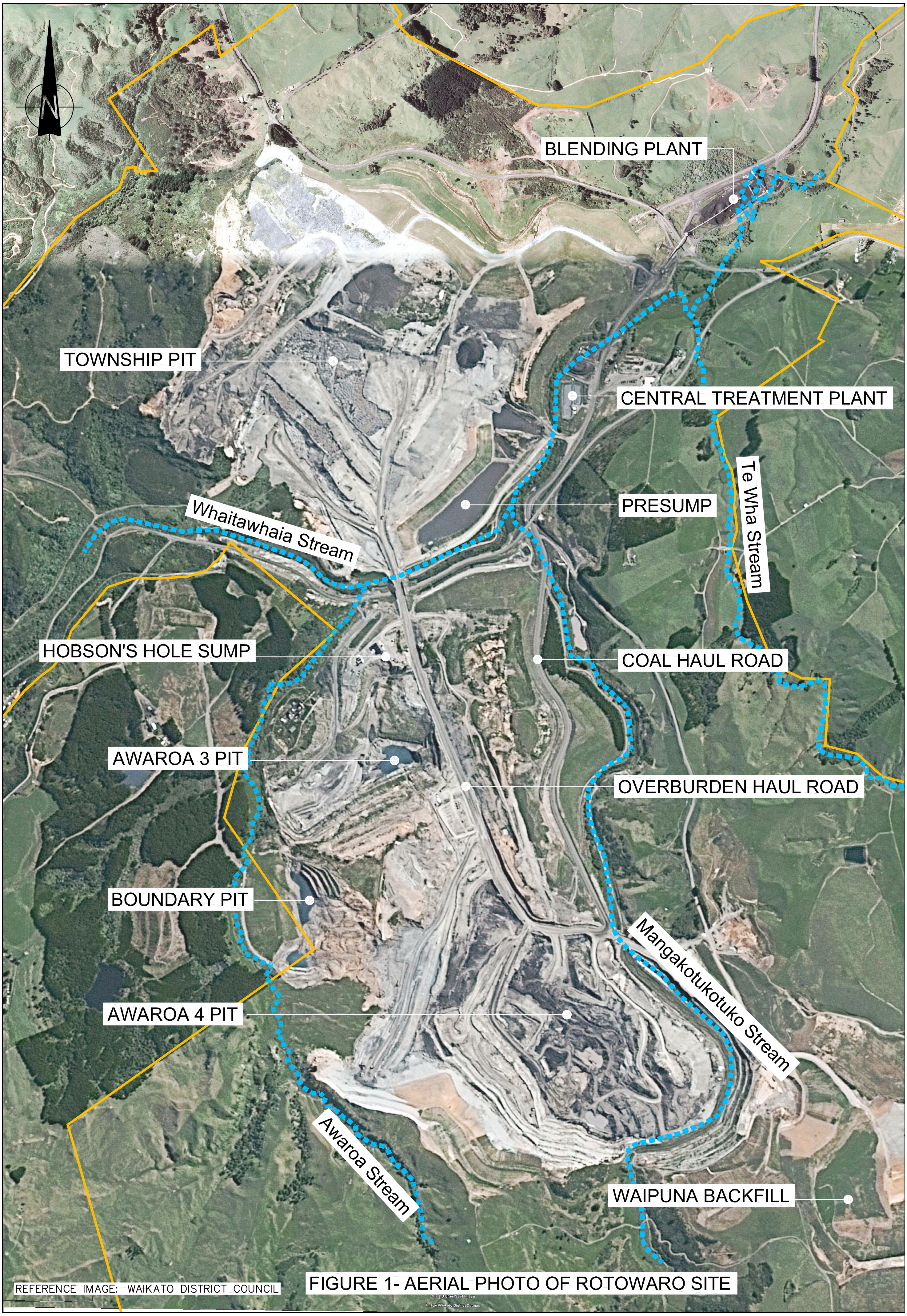

FIGURE 1- AERIAL PHOTO OF ROTOWARO SITE

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on site, the Waipuna Treatment Plant (WTP) that services the Waipuna Pit, a self-contained system (refer to Figure 2 for locations).

Most of the "dirty" water generated on the site collects at the lowest points of the mine pits and is pumped to the CTP. Intermediate sumps between the mine pits and the CTP (necessitated by the limits in distance and hydraulic head of submersible pumps) provide some storage and flexibility of pumping operations. The pumps used on-site are mainly submersible pumps operated with automatic float switches, triggered by water levels. Any excess runoff that exceeds the capacity of the pumps remains in the mine pits until the pumps can clear the temporarily flooded pit floor.

The CTP has ample capacity for average runoff flows generated from the site, but storage is necessary to manage the peak runoff flows from storm events. Traditionally this has been managed by in-pit storage, but this can cause interruptions to mining activities.

The expansion of the mine site to include the Awaroa 4 pit has placed additional demands on the water management system. The larger mine area has resulted in a greater volume of "dirty" water (from a larger geographic area) to be managed. Difficult mining conditions in the Awaroa 4 pit make interruptions to mining due to excess water less tolerable. In addition, there has been a reduction in available storage on-site due to backfilling of the Township pit, which had been used to store runoff in excess of the capacity of the CTP. For these reasons a large, purpose built sump, the "Pre-sump" was constructed in the Township backfill. The Pre-sump provides storage and pre-treatment prior to water flowing to the CTP. Completed areas on the site are also being actively rehabilitated (such as the completed Waipuna backfill) which can then be separated from the "dirty" water system and allowed to discharge directly to the natural watercourses.

1.3 WATER MANAGEMENT INFRASTRUCTURE

The water management system at the Rotowaro site has developed as the mining operations have expanded. The system comprises (refer to Figure 2 for locations):

- clean water diversion drains;
- dirty water drains;
- 12 storage sumps of various sizes (the mine pits usually contain a sump);
- 22 submersible pumps generally with elevation activated float switches;
  and an extensive network of pipelines being predominantly HDPE pipeline of varying diameter; and
- CTP and WTP water treatment plants.

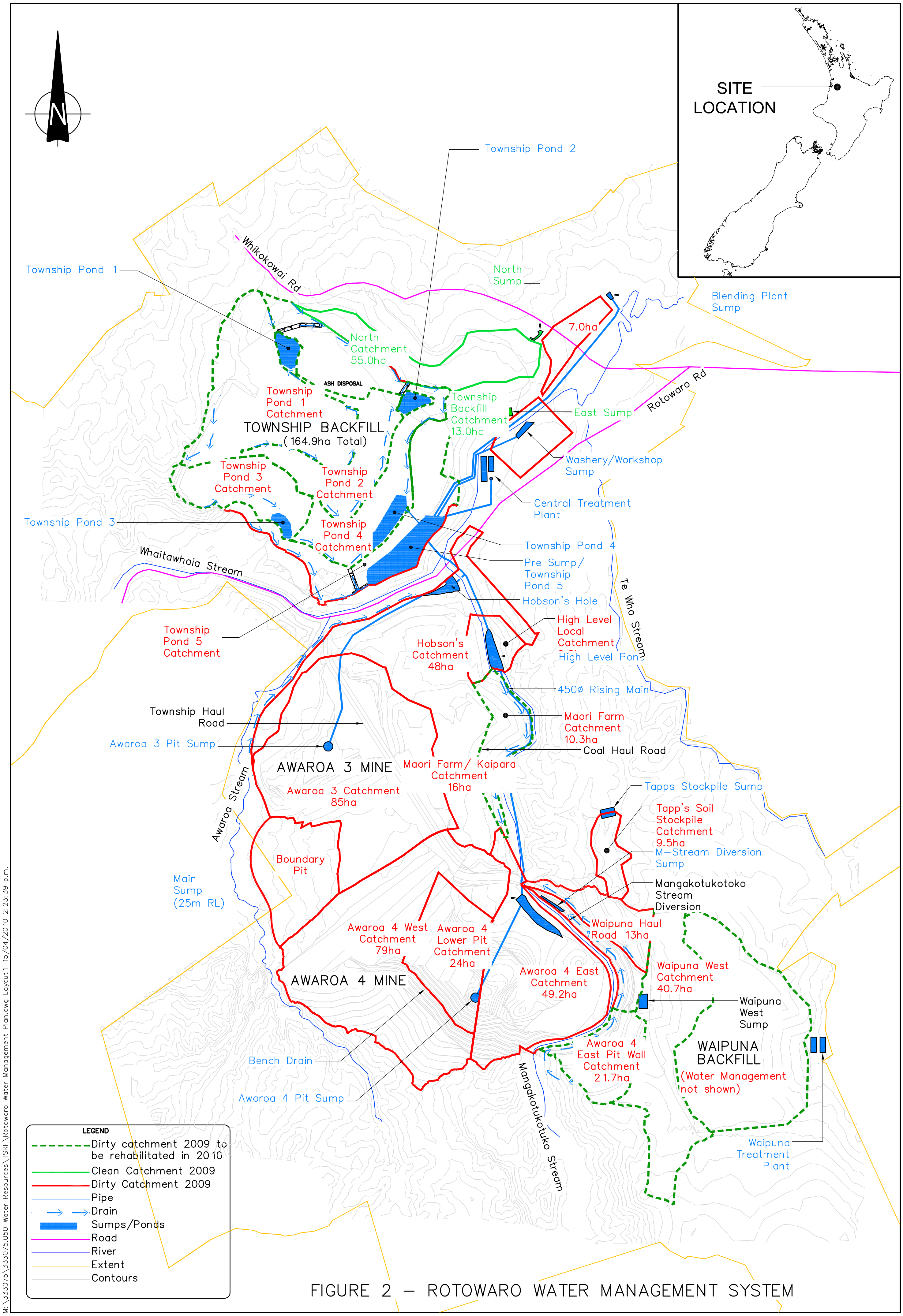


FIGURE 2 – ROTOWARO WATER MANAGEMENT SYSTEM

Figure 3 - A submersible pump supported by a flotation raft in the Awaroa 4 pit sump

The key storage sumps/mine pits at Rotowaro that are referred to in this paper include:

- Awaroa 4 pit – sump in the operational pit from which the majority of the coal from the site is won
- Awaroa 3 pit – a pit which is not currently actively mined, but has not been rehabilitated
- Township pit – a mine pit which is currently being mined at upper levels, while simultaneously areas are backfilled (resulting in diminishing available storage for dirty water)
- The Pre-sump - a 530,000 m^3 purpose built storage, pre-settlement and mixing facility
- Hobsons Hole sump– an intermediate sump
- High level sump – an intermediate sump
- Magnums sump – a collection sump for Awaroa 4 east high wall catchments
- Blending Plant sump – a sump for blending plant area.

1.4 WATER MANAGEMENT ISSUES AND OBJECTIVES

Water management at the Rotowaro site is vital to the operation, the two key issues at the site being:

1) Water in the opencast mine pits interfering with coal winning operations; and
2) Risk to the local environment from overflows of dirty (untreated) water to local streams.

All runoff from pit catchments drains to the base of the pit. From there it is pumped via intermediate sumps to the CTP. However, when inflows exceed the pit pumping capacity, or if downstream constraints in the system require pumping from the pit to be stopped, dirty water accumulates in the pit base. Significant volumes of water in the pit base affect coal winning operations and result in a loss of coal production. Risks to geotechnical stability of the pit walls can also increase with rising water levels.

While Solid Energy is required, and does, operate the Rotowaro mine in accordance with the conditions of the resource consents it holds, it also proactively aspires to meet, and exceed, current industry standards, for example those set out in Environment Waikato's Guidelines for Erosion and Sediment Control (Environment Waikato, 2009). The consents require treatment of all water discharged from site and set upper limits for the water quality of the discharges, including:

- Total suspended solids (TSS) of 50 g/m^3
- Turbidity of 50 NTU
- Soluble aluminium of 0.2 g/m^3

To ensure that that the limit for TSS is met, the discharge from the CTP has a turbidity meter and automatic shut-off valve that activates if the discharge water quality does not comply with the consent limits.

Overflows from some of the sumps (specifically the Hobsons, High Level, Magnums and Blending Plant sumps) have the potential to cause the discharge of untreated "dirty" water from the site. Solid Energy wants to ensure that there are no overflows from the system, therefore the objectives of the water management system are to:

1) reduce the risk of coal-winning operations being affected by pit flooding to an acceptable level;
2) prevent untreated dirty water discharges; and
3) ensure cost-effective and sustainable solutions.

Other considerations for water management planning at Rotowaro include:

- Flexibility to cope with the dynamic nature of mine operations;
- Site constraints, and the nature of mining operations creating large volumes of dirty water runoff, needing to be pumped over significant distances and elevation differences; and
- Developing water management infrastructure that meets the requirements of both Solid Energy and the mining contractor.

2 METHODOLOGY

2.1 CRITERIA

The water management objectives were refined in 2009 to develop criteria for the water management planning. These criteria are:

- Minimising flooding of the pit floor to 30 days/annum for the 10% AEP (10 year return period) event. Flooding defined to occur when the water volume in the pit exceeds 25,000 m^3, which is the nominal volume of the pit sump.
- That there are no uncontrolled discharges off the site up to and including the 5% AEP (20 year return period) event.

2.2 MODELLING AND HYDROLOGY

2.2.1 CHALLENGES

The challenges due to the nature of operations at Rotowaro require a different approach to traditional methods of event and/or design storm modelling. This is because individual components of the water management system respond more critically to different rainfall durations. For example:

- Drains – critical response to short duration intense rainfall events, e.g. high intensity rainfall (10min time of concentration)
- Sumps - critical response to rainfall events 1-5 days in duration, e.g. from major weather systems
- Mine pit - critical response to rainfall over a period of 3 months or more, e.g. from a consistently wet winter.

In addition, the changing nature of pit operations over time requires a comprehensive analysis of risk that can be readily updated and incorporated into mine planning as the site develops. Solid Energy analyses and manages risks as part of its mine and business planning, and therefore a risk-based approach to water management complements its existing management systems.

2.2.2 SWMM MODEL

The US Environmental Protection Agency's Stormwater Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of sub-catchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps and regulators. SWMM was first developed in 1971, and has since undergone several major upgrades. The model is freeware, so Solid Energy, its consultants and other parties can use it free of charge.

The SWMM modelling software was selected for use at the Rotowaro site due to its strengths which include:

- The ability to simulate a long period of rainfall;
- The use of the SCS curve method of runoff calculation, the method preferred by various regulatory authorities in New Zealand;
- The ability to compute extensive drainage networks with relatively short run times;
- The ability to model elements such as storage/treatment units, flow dividers, sumps, pumps, weirs, and orifices; and
- The ability to model control rules for the water management system, such as manual over-ride of pump automatic controls.

2.2.3 ROTOWARO MODEL

The issues of concern to Solid Energy, as previously outlined, are pit flooding and overflows to the environment that can occur when storage in a sump is exceeded. These issues relate to the total volume of runoff rather than peak flows.

The availability of daily rainfall records (rather than more frequent measurements) limits the applicability of the model to longer duration events. However, this is acceptable because the sumps and pits are most sensitive to total flow and generally the critical response is to rainfall events of time scales greater than a day. For components of the water management system that respond to shorter duration events, such as drains and smaller sumps, design can be undertaken using other conventional design storm approaches.

Therefore, the SWMM model is essentially run as a long-term water balance model, where water storage in the pits, sumps and through the CTP is simulated. The model is run for a long-term rainfall record, which assesses the theoretical performance of the water management system for the rainfall events that have been experienced at the site over the last 25 years. The use of real rainfall records has been found to be important at Rotowaro, as the critical events for different components of system can be determined.

The SWMM model enables the theoretical performance of the water management system and different potential options to be analysed.

2.2.4 RUNOFF

The runoff from catchments is simulated with the US Soil Conservation Service (SCS) method. The SCS curves numbers adopted for modelling were 89 and 48 for pits and other catchments, respectively, based on the calibration (refer Section 2.2.6 below).

Losses to ground and evapotranspiration were not directly simulated, but are indirectly accounted for in the SCS method. The daily rainfall records from Te Akatea (approximately 5 km away) were used for input in preference to site rainfall records because they provided a more accurate and complete (1984 – 2009) record. For modelling purposes the daily rainfall record was uniformly divided into the calculation time step of 5 seconds.

2.2.5 PUMPS AND SUMPS

Existing pumps and sumps were incorporated into the model. Pumps are turned on/off in the model when the water level in the associated sump rises/falls above or below certain thresholds (accuracy to 0.1m). Only the live storage of the sumps was modelled. The pumps operate at a fixed flow-rate. There is no allowance for variable flow rates caused by pumps operating on the same rising main (e.g. High Level Sump and Hobsons Hole pump through same 450 mm dia. rising main). In the model overflow was not allowed from sumps, so that flow was not lost from the system. This allowed the maximum required sump volume without overflow to be calculated. Where volumes exceed the available live storage in a sump, overflows would have occurred.

The model uses control rules to simulate the mine operator’s response to extreme rainfall events in accordance with the site Emergency Response Plan for rainfall events. The control rules turn off Township, Awaroa 3 and Awaroa 4 pumps when the flow at the CTP exceeds 300 l/s, to hold back water in the mine voids to protect intermediate sumps and the CTP from overflowing. The choice of control is a simplification of the Emergency Response Plan, so that it could be simulated by the model. In reality the mining operator’s personnel turn off the pumps based on their judgment of the potential for an emergency considering CTP flows; sump water levels, rainfall and forecasts. The modelling can be used to inform the Emergency Response Plan to reflect the best operational procedures identified by the simulated results.

2.2.6 CALIBRATION AND VERIFICATION

The model was set up and calibrated in 2003 using the process outlined below. A further check by comparison of the simulated and observed peak flood volumes in the Awaroa 4 pit during the winter of 2008 (modelled in 2009) gave some confidence in the results being produced.

Calibration to total flow

Calibrating the model for the mine operation was difficult due to a constant change in mine operations, e.g. it being an active mine area; catchments and changes to pump configurations; the lack of flow and continuous, site-specific rainfall data. The model was calibrated for total flow rather than more specific storm events because of the quality of the data and because total flow was the focus of the modelling.

A period in 2003 provided the best dataset for calibration as total flow through the CTP was measured with concurrent pumping rates measured in the Township pit. Data for calibration was available for rainfall at Te Akatea, CTP flows for September 2001 to February 2004 and Township Pump flows from June 2003 to January 2004. For the calibration runs, the catchments and water management infrastructure of 2003 were represented in the model.

The calibration was a two-step process. Firstly, runoff in the Township Pit was calibrated by adjusting SCS runoff parameters for the Township Pit until the runoff volumes agreed with the total flows from Township pump records. Secondly, all "other" catchments (consisting of backfills, haul roads and minor pits) were calibrated by adjusting SCS runoff parameters until total runoff volumes matched total runoff volumes at the CTP.

The calibrated SCS curves numbers were 89 and 48 for the Township and "other" catchments respectively. Soil response time (R) was assumed to be 10 days for all catchments. Soil conductivity (C) for the Township mine was taken as 1 mm/day and for all other areas as 5 mm/day. The SCS runoff parameters are physically reasonable given the catchment cover and geology types.

The calibration results are given in Table 1 in terms of percentage runoff. The two catchment types - Township Pit and "other" – and the total catchment had simulated total 2003 runoffs that were within 1% of observed total 2003 runoffs.

Table 1: Results from calibration of 2003 total flow

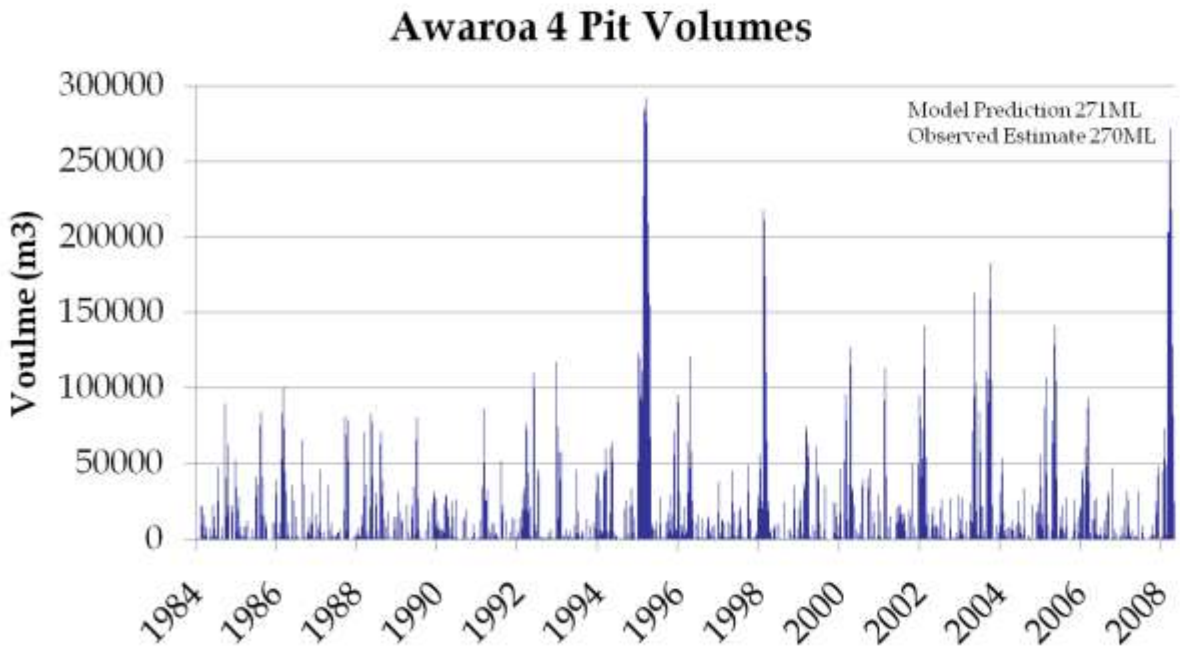
Catchment	**Observed runoff (%)**	**Modelled runoff (%)**
Township Pit	68.0	67.3
Other (Rotowaro excluding Township)	20.7	21.7
Total Rotowaro	37.7	38.7

The data also showed that the monthly rainfall recorded at the mine was 15% less than the monthly totals at Te Akatea. It is important to note that the model was calibrated to Te Akatea rainfall.

Verification of model for winter 2008

During work carried out in 2009 by Tonkin and Taylor Limited ("Tonkin & Taylor"), the simulated peak volume in the Awaroa 4 pit for the winter of 2008, using a model representing the catchments and water management infrastructure at that time, was compared to the observed peak volume in the pit (refer Figure 4). The model predicted a volume of 271 ML (1ML =1, 000 m^3) compared to the observed estimate of 270 ML (a difference of 0.4%). It is not claimed that the model is as accurate as this comparison suggests, but this result gives some confidence in its ability to be used as an appropriate tool for analysis and water management planning.

Figure 4: Awaroa 4 pit simulated volume for water management system as at February 2009 using 25 years of rainfall including the winter of 2008



2.3 RISK-BASED REPORTING

The model results can be presented probabilistically to show the risk of flooding of pits/sumps for different management options. Each of the water management options were simulated using the 25 year rainfall record. The performance (volume or flow) for any given component in the water management system can then be analysed for the 25 years of available data. Figure 4 gives an example of the performance of the Awaroa 4 pit sump for the 25 year rainfall record.

These data were converted into an annual maximum series by identifying the peak volume each sump experienced in each calendar year, and then ranking these from the largest to the smallest. Generalized extreme value distributions were not used because these are untested for this application involving volumes and operator interventions via control rules. The largest value, occurring only once in the 25 years, infers simply that the water volume in the sump has a 4% probability of exceeding that value in any subsequent (or any given) year. The median value reached for the sump of the 25 annual peaks in volume, would have been exceeded in approximately half the years, and therefore it is inferred that the sump has a 50% probability of exceeding that value in any year. The smallest value of the annual maximum volume series was exceeded in every other year during the 25 years, and therefore is predicted to be exceeded in the subsequent (or any given) calendar year. These and the remaining calculated probabilities are plotted for each sump, to quantify the probability (or risk) of the sump exceeding a certain volume in any given calendar year for a given water management option. The probabilities generated represent an estimate of the Annual Exceedance Probability (AEP) of a given volume being exceeded (Figure 5).

A presumption with this analysis is that the 25 years of rainfall record is statistically representative of long-term (and future) rainfall. From the historic rainfall data set the

10% AEP and 5% AEP rainfall depths gave similar values to those estimated by HIRDS version 1.5.

The peaks in volume for different sumps or pit voids were identified independently of one another, and may be in response to different rainfall events out of a series of events in each calendar year. Therefore a more realistic probability of exceedance based the most critical rainfall patterns for each individual sump is generated, than one based on a theoretical design storm assumed to occur over a 24 hour period.

3 CASE STUDY

3.1 INTRODUCTION

The risk-based reporting using SWMM model results has been used to assist in a number of decisions around the water management at Rotowaro over a period of seven years (2003 to 2009). These have included:

- planning the water management infrastructure for Awaroa 4 pit;
- the decision to construct the Pre-sump and the design of its volume to provide adequate storage within the system, also providing pre-mixing and settlement prior to the CTP;
- the installation of extra pumps in the Awaroa 4 pit base;
- the operational trigger levels for storage and pumping in the Hobson's Hole sump;
- the operational trigger levels for pumps within the Awaroa 3 pit void to minimise geotechnical risks; and
- pumping from the Boundary pit
- prioritising the rehabilitation of backfilled areas to remove catchment from the water management system.

Modelling and the risk reporting methods undertaken by Tonkin and Taylor in 2009 using the SWMM model are described as a case study in this section. The main objective in 2009 was to reduce the flooding risk in the Awaroa 4 pit, after a wet winter in 2008 had severely hampered operations. The SWMM modelling and risk-based reporting enabled possible water management options to be compared, and provided data for Solid Energy to make decisions on a clear understanding of what the risks were to business operations.

3.2 OBJECTIVES

The objective of the modelling was to review the risk of flooding in the various site sumps, and evaluate possible water management options.

The key water management issues facing the Rotowaro opencast mining operation at the time of the modelling were:

- increasing catchment sizes for dirty water to be treated by same treatment plant;
- diminishing on-site storage, due to the reduction of storage in the Awaroa 3 and Township pit voids; and
- challenging mining conditions in the base of Awaroa 4 requiring good management of water.

The objectives for water management were as follows:

- minimising operational outages due to flooding in the base of the Awaroa 4 pit;

- eliminating environmental incidents and breaches of resource consents by spillage of dirty water (untreated) from the water management system;
- minimising geotechnical risks that might arise from management of surface water; and
- ensuring water management infrastructure is cost-effective and robustly designed. The risks were to be minimised by design where ever possible. The mining operator desired a lower level of operational intervention than had previously been required.

While the most pressing concern was flooding in the Awaroa 4 pit, this issue cannot be isolated from the rest of the water management system.

Flooding within the Awaroa 4 pit (such was observed in winter 2008) typically occurs due to the capacity constraints of the downstream sumps and CTP, so pumping in Awaroa 4 has to cease to prevent overflows to the receiving environment. Therefore, to reduce the risk of flooding in Awaroa 4, a review of the whole system was necessary with consideration of measures to reduce runoff, increase storage and increase throughput of water.

3.3 CONCEPTS

The water management system (as it existed in early 2009)and four potential concepts to provide improvements to the system were modelled. The concepts are briefly explained below:

3.3.1 CONCEPT 1

Concept 1 was for the removal of rehabilitated areas from the "dirty" water system. This resulted in a reduction in catchments and runoff to be treated by the CTP.

Additional measures focused on maximising the use of the pre-sump storage for the Karaka, Township and Township North sumps to be diverted to the Pre-sump, that had previously pumped directly to the CTP. In addition the pumping system was rearranged so a pumped rate of 60 litres per second (l/s) could be achieved from Karaka and 150 l/s from the Awaroa 4 pit (where previously the maximum combined rate had been 135 l/s).

3.3.2 CONCEPT 2

Concept 2 built on the changes for Concept 1 and incorporated the following additional adjustments with the aim of reducing the risk of overflows from Hobsons Hole and further utilising the Pre-sump:

- Hobsons Hole storage volume increased to 4ML (from 3ML) and pumping from Awaroa 3 turned off when sump reaches 75% volume;
- Hobsons Hole pumping capacity increased to 250 l/s (from 150 l/s) when sump reaches 75% volume;
- Pre-sump pumping capacity increasing to 150 l/s (from 75 l/s) when volume reaches 100ML and 400 l/s when volume reaches 200ML; and
- High Level and Hobsons pump to Pre-sump.

3.3.3 CONCEPTS 3 AND 4

Concepts 3 and 4 explored the option of increasing pumping rates from the Awaroa 4 pit to reduce the severity of flooding in the pit. Concept 3 proposed increasing pumping to 200 l/s (from 150 l/s). Concept 4 proposed increasing pumping from both Awaroa 4 and High Level Sump to 300 l/s (from 200 l/s).

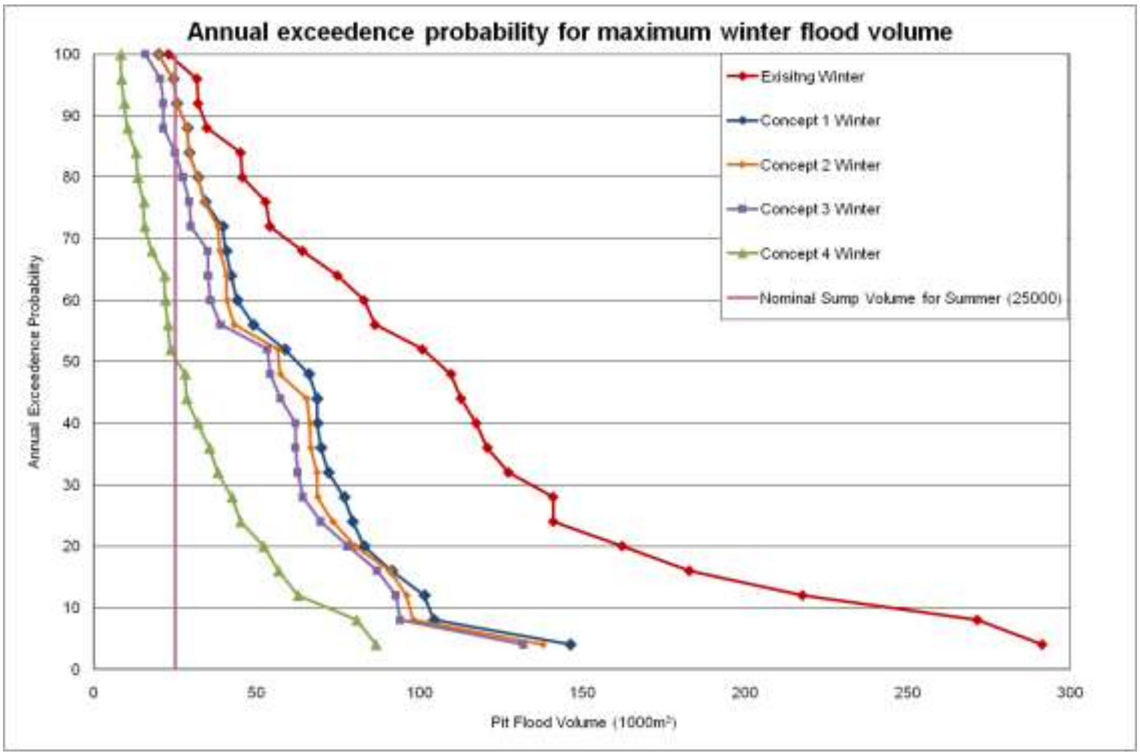
3.4 RESULTS

The results for volume in each of the critical sumps and pit voids were reported probabilistically. The results for Awaroa 4 pit void and Hobsons Hole sump are discussed in this section. For Awaroa 4 pit void the design criterion was to minimise flooding causing operational interruptions. For Hobsons Hole the criterion was to reduce the risk of overflows off the site.

The duration of flooding is also critical to pit operations and so the number of consecutive days that the nominated acceptable volume of water in the pit was exceeded was also plotted probabilistically.

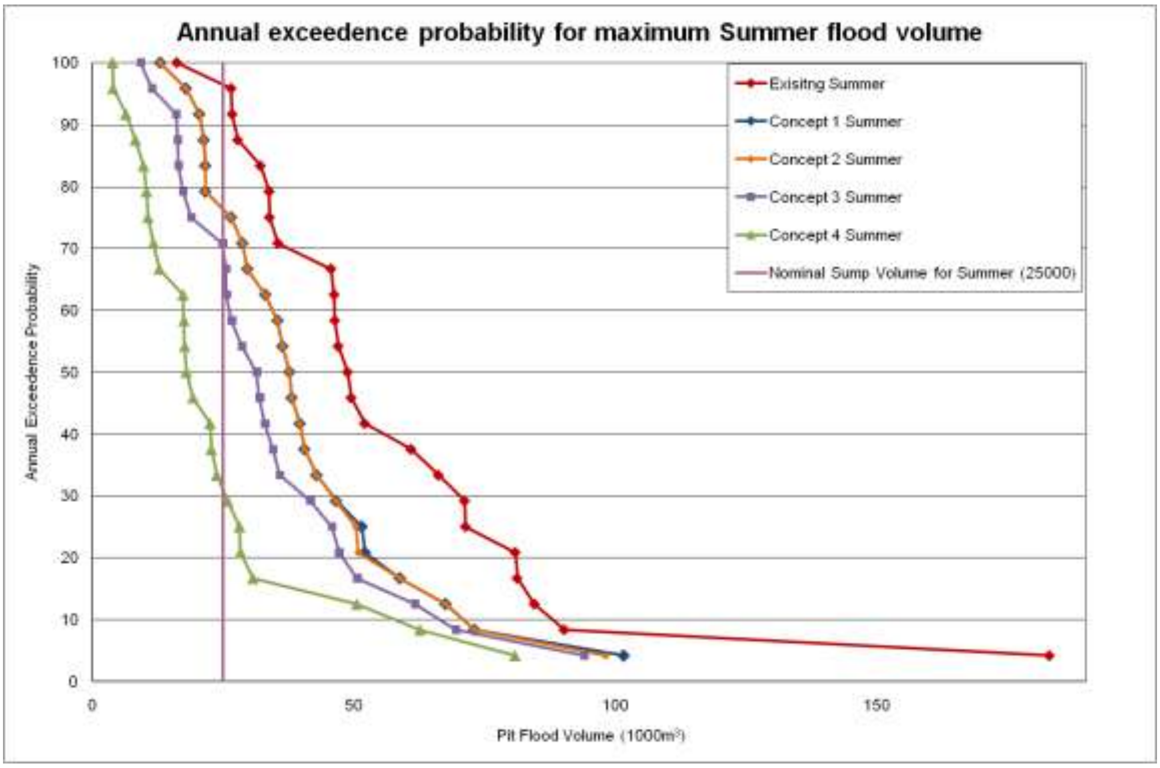
The probabilistic plots generated for Awaroa 4 flooding are shown in Figures 5, 6 and 7. Winter (May to October inclusive) and summer (November to April inclusive) results are presented separately as Solid Energy wanted to assess schemes that required coal-winning from the base of the pit during summer, with coal-winning from higher seams during the winter.

Figure 5 - Probabilistic plot of data for flood volume during winter in Awaroa 4 predicted for different water management concepts



The 4% AEP event for the existing water management infrastructure in Awaroa 4 was predicted to have a maximum flood volume reached of 290 ML. The water management concepts demonstrated significant improvements, with the 4% AEP event for Concept 1 having a maximum flood volume of 150 ML. Concepts 2 and 3 gave slight improvements on this volume. Concept 4 modelling results showed a further reduction to approximately 80 ML. For the 50% AEP event Concepts 1, 2 and 3 gave maximum volume reached predictions of approximately 75 ML.

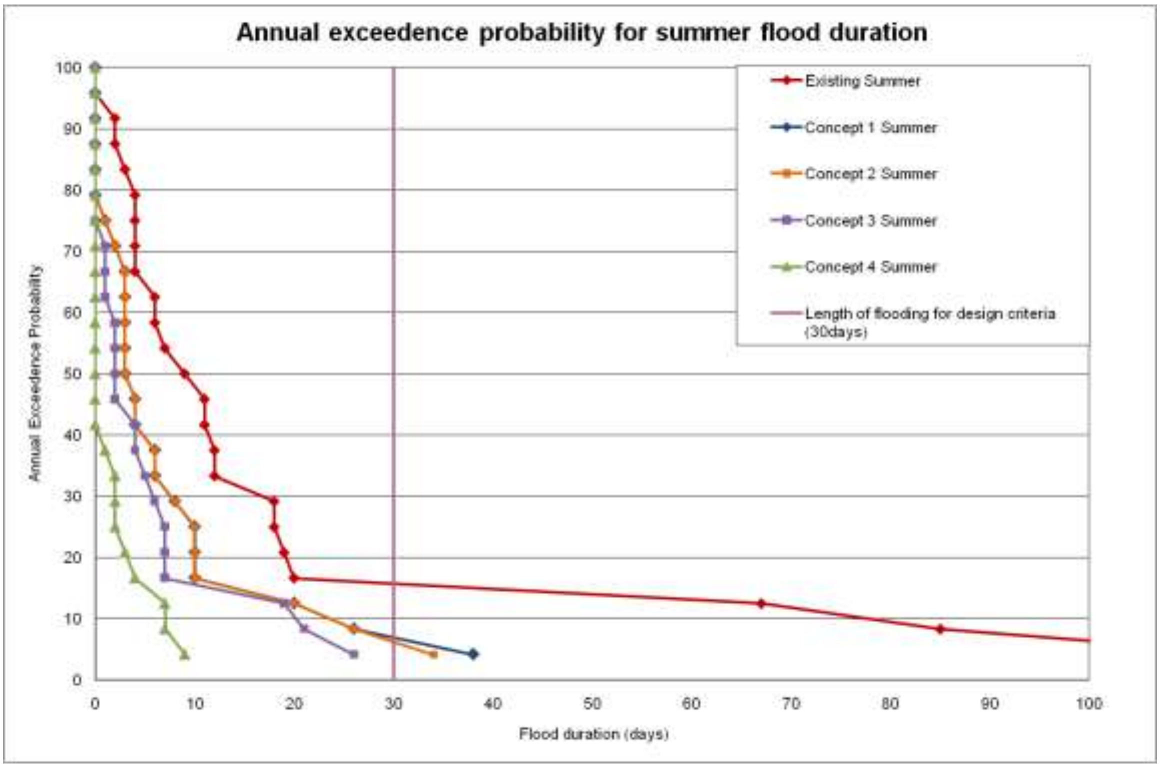
Figure 6 - Probabilistic plot of data for flood volume during summer in Awaroa 4 predicted for different water management concepts



During summer a manageable pit sump volume was assessed by the mine operator to be 25 ML. For Concepts 1 and 2, there was an approximately 25% probability that the maximum volume would be kept within this value over the summer period, as shown in Figure 6.

The duration of flooding or number of days during the summer for which the nominal sump volume was predicted to be exceeded for Concepts 1 and 2 was 3 days for the 50% AEP event, 10 days for the 20% AEP event and approximately 23 days for the 10% AEP event as shown in Figure 7 below. A duration of flooding of 30 days was used as a benchmark for acceptable operating conditions.

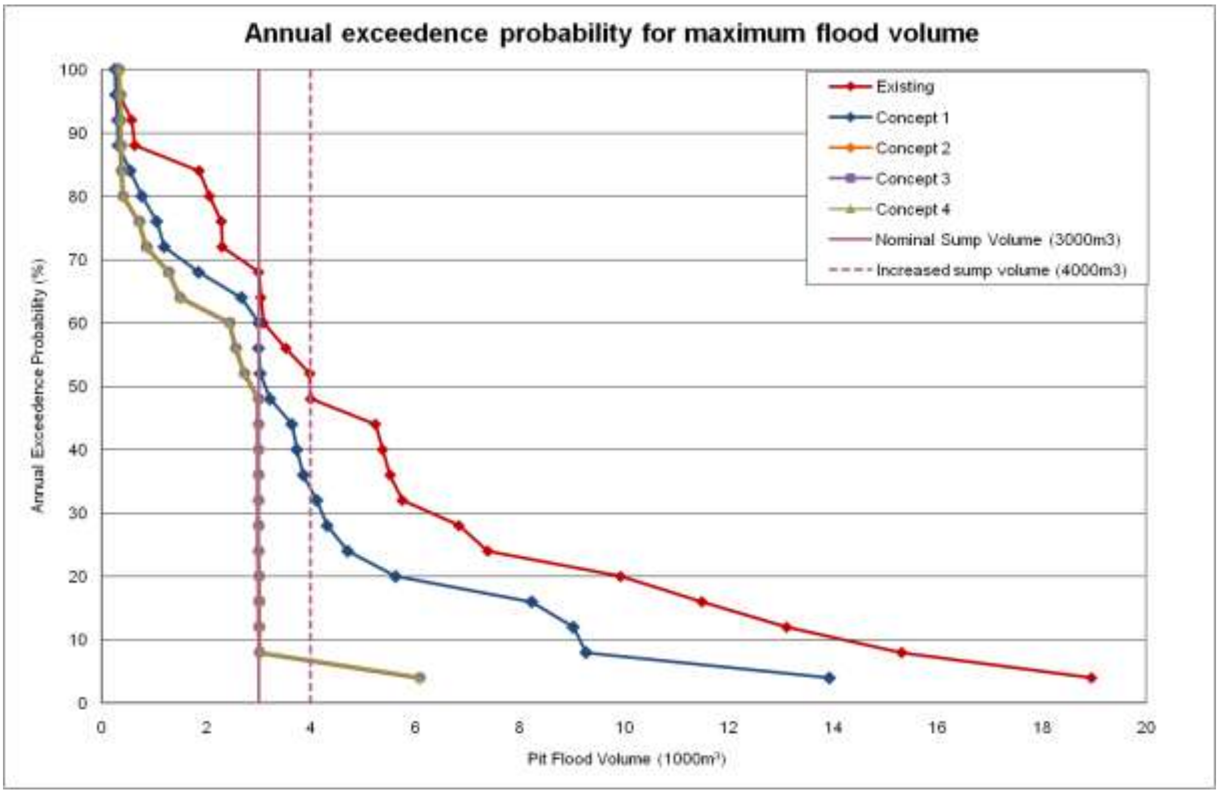
Figure 7 - Probabilistic plot of data for duration of pit flooding exceedance during summer in Awaroa 4 predicted for different water management concepts



Hobsons Hole

There is a risk of overflows from the Hobsons Hole sump due to pumped inflows, a large local catchment and low storage volumes. Therefore this sump needs careful management to ensure that consent conditions regarding discharges are met. Figure 8 below shows the how the operational changes proposed for Concepts 2, 3 and 4 combined with an enlarged sump volume of 4ML would have prevented overflow in 24 out of the 25 years modelled. However, to ensure the 5% AEP event would not cause the sump to overflow, a sump volume of 5 ML would be required, or the option of extra pumping available at short notice (the events which are most critical for this sump are the 1 or 2 day rainfall events, rather than the longer duration wet weather that is critical for the Awaroa 4 pit).

Figure 8 - Probabilistic plot of data for flood volume exceedance in Hobsons Hole sump predicted for different water management concepts



3.5 CASE STUDY CONCLUSIONS

The case study summarises work undertaken to assess options to reduce the risk of flooding in the Awaroa 4 pit. A key finding was that improvements to the flood risk in Awaroa 4 could be made by making efficiency improvements elsewhere in the water management system. Recommendations for improving the water management system based on the SWMM modelling results and risk-based approach included:

- diverting rehabilitated catchment areas out of the dirty water system;
- diverting the Waipuna West catchment to the Waipuna Treatment Plant;
- diverting all CTP inflows to the Pre-sump for benefits in water quality from improved treatment performance and to minimise interruption to pumping from the Awaroa 4 pit;
- pumping clean groundwater flowing into the Awaroa 4 pit to Mangakotukutuku Stream;
- considering increasing pumping rates from the Awaroa 4 pit to reduce the number of days of flooding and interruption to pit operations;
- increasing the volume of Hobsons Hole and when sump storage reaches 75% of volume, turn off pumping from Awaroa 3 and increase Hobsons pumping;
- either increasing the pumping rate from the Blending Plant sump or increasing its volume; and
- considering pumping directly from Awaroa 3 to the Pre-sump.

Solid Energy was able to adopt these measures with a clear understanding of the likely outcomes and risks of each, enabling it to carry out risk-based costing exercises.

4 OUTCOMES FOR SOLID ENERGY

The SWMM modelling package enabled simulation of long-term rainfall records and the generation of probabilities for sump and pit storage volume requirements. The results can be presented in a way that shows the risk of flooding of pits/sumps, and how effective different management options would be for reducing this risk.

The use of historic rainfall records has been found to be important for modelling of the water management system at Rotowaro because different components of the system are sensitive to different timescale rainfall events and therefore 24 hour typical design storms are not relevant . For example sumps are at risk from relatively short duration events, whereas pits are most at risk from longer duration wet weather periods.

The benefits of simulating a long-term rainfall record rather than a design storm included the ability to identify the greatest volume reached for each component, regardless of the duration of corresponding rainfall event. Thus a more accurate assessment of the Annual Exceedance Probability distribution of volumes for each component could be made. The SWMM modelling and use of the local rainfall record was the only way to investigate this highly complex system with its internal feedbacks.

The risk-based reporting system, with the results presented in probabilistic plots enables Solid Energy to carry out risk-benefit analyses and to make informed decisions regarding the water management system at Rotowaro.

5 CONCLUSIONS

A methodology for analysing operational and environmental risks associated with water management is proposed that is based on the site rainfall record and hydrological modelling. This method is applicable for situations where generic design storms are not appropriate. The EPA SWMM model with local, long term rainfall records can be used to simulate the performance of the water management infrastructure and options for improvements. The advantages of this approach include being able to model and evaluate the response of a system over the entire period of historical rainfall data with all the different imbedded timescales. This approach captures the responses of individual components of the system when they are highly dependent on each other, yet respond critically to different duration rainfall events. A risk-based method of reporting the modelling results provides designers and decision makers with the information needed to carry out risk-benefit assessments to assist in decision making.

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REFERENCES

Environment Waikato (2009) *Erosion Sediment Control Guidelines for Soil Disturbing Activities*

T&T (2004) *Awaroa 4 Water Management Plan*

T&T (2007) *Awaroa 4 Flood Risk – Water Management Options Report*

T&T (2009) *Rotowaro Water Management 2009*

USEPA (2010) – *www.EPA.gov 23 March 2010*

SOLID ENERGY (2010*)* - *www.coalnz.comviewed 21 March 2010*