Research Report
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Water balance modeling using weather forecast

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Table of contents

1 Introduction

Water quantities have a major role in a mine risk management. The understanding of local hydrology is needed in order to keep track on volumes of available water in a surrounding area of a mine. The information on areal water balance also helps to manage the inner water balance of a mine. Changes in areal water balance can affect to the production planning. For example, the mining operators need to know when to dispose any excess water that is stored to the area.

One way to follow the water balance is use different observation in water bodies and ground. However, this requires large resources to keep up the continuous situation awareness just using measurement. The areal water balance can be modelled to get the important information without an extensive observation network. The water balance model can simulate the water balance continuously. With a model, it is also possible to forecast changes in water balance. This helps to prepare for any problematic events relating to water quantities. In this report, we propose a concept of using Watershed Simulation and Forecasting System to simulate areal water balance of a mine to support to risk management and decision making.

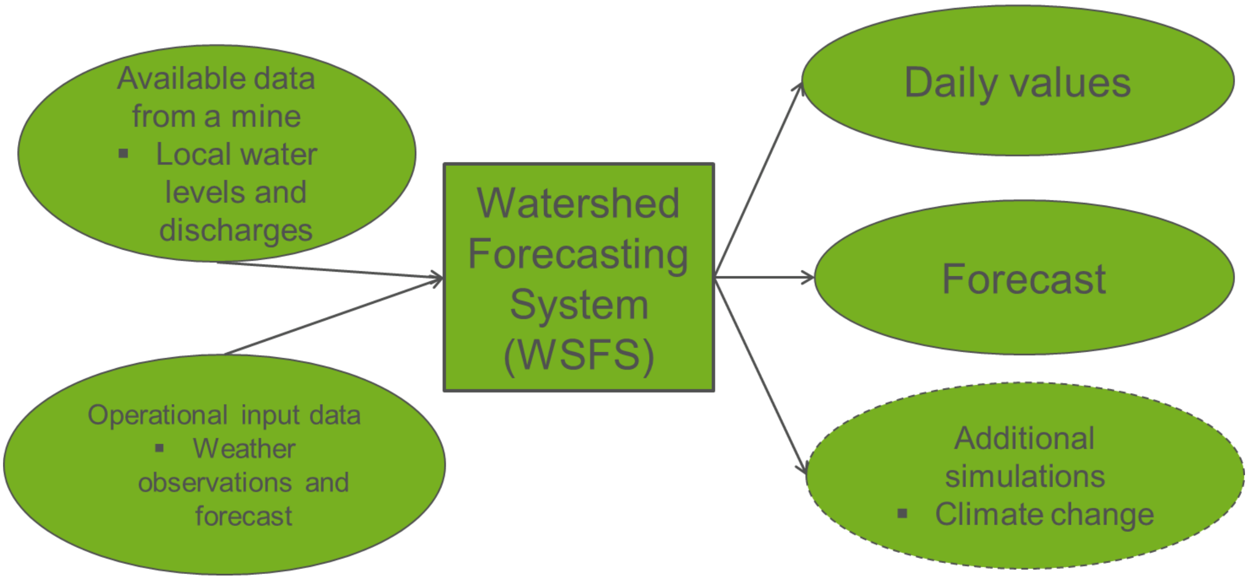
2 Areal Water balance modelling with WFSF

An amount of available water in a certain area can be determined with an areal water balance. This includes several components: inflow to the area, outflow from the area, precipitation, snow, soil moisture, ground water, runoff and evaporation from land and lakes (also reservoirs and process polls). Watershed Simulation and Forecasting System (WSFS) is able to simulate the daily areal water balance component-wise (hydrological variables listed above) to a given area. The model is based on the rainfall - runoff concept. The system is also capable of forecasting the changes in the water balance with weather forecast.

The WFSF operational simulation is done for every sub-basin covering the whole Finland. The system gets automatically the newest observations of temperature, precipitation, water level, discharge and other needed data provided by Finnish Meteoroidal Institute or SYKE or other sources. The system uses observations also to follow-up the simulation and forecasting accuracy. A short-term forecast is done using Ensemble Prediction Weather Forecasting data (VarEPS) as an input whereas a long-term forecast uses additionally also histological weather data.

With the system, it is possible to focus the simulation to a specific area, for example, a mine (figure 1). This way the information of water balance can be provided area-specifically. This could be for example discharge information from a local river used by a mine. The local observations from a mine can be used to improve the simulation accuracy. In addition, the system can simulate water balance using different scenarios, such as climate change.

Figure 1 Using WSFS for areal water balance simulations



3 Watershed Simulation and Forecasting System – model description

The water balance simulations are performed with the Watershed Simulation and Forecasting System (WSFS) developed and operated in the Finnish Environment Institute (Vehviläinen 1994). The WSFS is used in Finland for operational hydrological forecasting and flood warnings (www.environment.fi/waterforecast/), regulation planning and research purposes. The main part of the WSFS is a conceptual watershed model based on the HBV-type model (Bergström, 1976). The basic structure of the WSFS is the HBV model structure, but there are differences in the river routing, watershed description and some process models such as the snow and evaporation models.

The hydrological model of the WSFS is semi-distributed as it is divided to over 6000 small sub-basins (40–500 km2) with their own water balance simulations (Vehviläinen et al., 2005). These sub-basins are connected to form the entire watersheds. The WSFS includes a precipitation model for evaluation of areal precipitation and its form, a snow model based on temperature index snow melt approach, a rainfall–runoff component that consists of a soil moisture, sub-surface and groundwater models, and lake and river routing models (Huttunen I. et al., 2015). All lakes in Finland with an area over 100 ha, in total approximately 2600 lakes, are included in the model.

The input data in the water balance simulations is daily precipitation and air temperature. The forecast is done using Ensemble Prediction Weather Forecasting data (VarEPS) as an input. The first 14 days of forecast are based on VarEPS. If a longer forecast is needed, the system uses historical weather data as an input after the 14 days period. Potential evaporation is calculated in the WSFS using air temperature, precipitation and time of year (an index for available net radiation) (Huttunen I. et al., 2015). This equation has been calibrated and verified against observations of Class A pan evaporation values (Huttunen I. et al., 2015). The actual evaporation is calculated from potential evaporation and the soil moisture deficit. The changes in temperature and precipitation affect the potential evaporation and in addition changes in soil moisture deficit affect actual evaporation. The method used here has the time of year as index of available radiation, which limits the increases of potential evaporation especially in winter, but is similarly a simple method of estimating potential evaporation.

4 Result delivery

The results of water balance simulations can be delivered automatically using various methods, such as FTP transfers, email and website-based data dumps. The delivery method and format can be decided based on requirements from a mine. All values are simulated on daily time-step for a local basin area of focus. The length of forecast can be determined by the client mine. The forecast can only consist of a median forecast or it can include different percentiles calculated from the ensample forecast.

Based on the needs of the mine, the simulation results delivery can contain the full set of variables affecting water balance or the most relevant ones. The variables are listed in Table 1 together with usability estimate for water risk management. The index is estimate how important variable is regarding to water risk management in mines.

Table 1 List on variables affecting water balance

variables	Type	Unit	Usability in water risk management (1-5)
precipitation	areal	mm	5
evapotranspiration	areal	mm	2
lake evaporation	areal	mm	3
snow storage	areal	mm	5
soil moisture	areal	mm	3

surface/sub-surface/ground water flow and storage	areal	mm	2
runoff	areal	mm	4
water levels of local rivers and lakes	point	m (difference to reference level)	5
discharge of local rivers and lakes	point	m^3/s	5

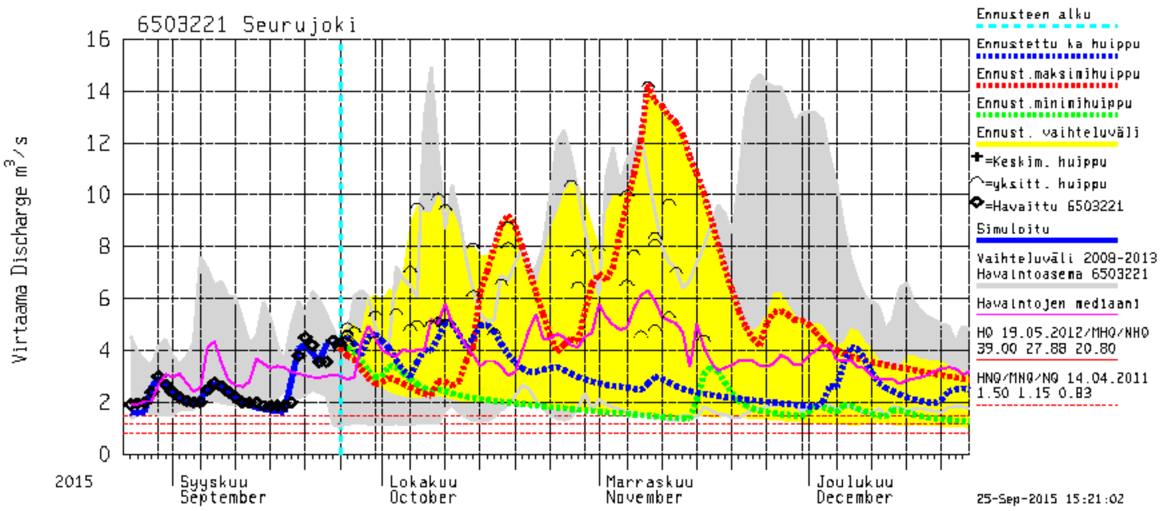
Depending on the area and a mine type, the usability of each variable may vary.

5 Mining use cases

The simulated water balance is an easy way to increase the situational awareness regarding the water related issues in a mine. With up-to-date information about water balance, there are better chances to deal with unusual situations caused by extreme weather events or during periods with exceptional seasonal weather. The simulated data can be used as an input for risk management systems to gain wider control over water quantities. In addition, the production planning can benefit from the forecasted changes in water balance. The data can beneficial when planning production phases or deciding on production volumes.

As a proof of concept, Agnico Eagle's gold mine in Kittilä receives the water balance simulations and forecast done with WSFS. The data is delivered daily with web-based data dumps. In addition to the areal variables listed in Table 1, the simulation includes the discharge in Seurujoki which is a river near the mine (Figure 2). The discharge information is needed for the production planning.

Figure 2 Discharge in Seurujoki. The forecast was done on Sep 25th 2015



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