Operational water balance model for Siilinjärvi mine

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Abstract A hydrological forecast model was developed for simulating and forecasting water balance in Yara Siilinjärvi mining area. The purpose of the model was to provide a tool for mining operators for better water management in the mining site. The resulting model is fully operational forecast system, which uses real time meteorological and hydrological data to simulate water balance, water level, discharge, snow and other quantities for each basin in the area. It is currently used by Yara Siilinjärvi mine for operational forecasts.

Key words mine, water balance, modelling, real time simulation, forecast

Introduction

Mining companies face several environmental challenges regarding water management in mining areas: risks caused by excess water are serious and can lead to flooding and dam breaches, as well as spilling substances into downward water ways. Predictive water management is required to forecasts such events and reduce risks at mining site.

In order to address these problems and to provide a tool for mining operators, a hydrological model was developed for simulating and forecasting water balance. The model was developed in Finnish Environment Institute (SYKE) as a TEKES project with collaboration of YARA Siilinjärvi mine, which was used as a pilot area. The model itself is based on the Watershed Simulation and Forecasting System (WSFS), also developed in SYKE. The WSFS consists of a hydrological, runoff and discharge models, and it monitors and forecasts the water levels and discharge of lakes and rivers in real-time. It is the main tool in national flood forecasting, and it has been used for operational water quality modelling as well as climate change research (Vehviläinen 1992, 1994, 2000, Veijalainen 2012). A number of hydrological variables such as precipitation, evaporation, runoff, soil moisture, groundwater storage, and snow pack, etc. are simulated for all catchments in Finland. A wide range of hydrological and meteorological observations are utilized in the operation of the model system.

The hydrological mining site model

Siilinjärvi mining site model is a modified version of the WSFS model. Schematic diagram of the model is shown in Figure 1. All hydrological process models that simulate the water balance, as well as most of the data assimilation routines, are the same as in the nationwide operational model. Implementation of the model to the mining area required a catchment description of the site. That is, sub-basins, reservoirs and discharges in the area had to be determined and modelled. This was established by using elevation data, public maps GIS-data, and reservoir data from Yara and the expertise of hydrologists in SYKE and local mine personnel. The division into sub-basins was made for the mining area as well as some of the immediate mine surroundings. GIS information consisting of basin areas and locations, outlets, streams, lakes and ponds was derived with the help of a Finnish watershed database available to SYKE. This catchment division is shown in the map in the user interface, shown in Figure 2.

Siilinjärvi site was divided into 28 sub-catchments, most of which contain one lake or pond. The hydrological model describes water balance and inflow in each pond. The water balance of the open mining pit is also included in the model, in order to provide estimates for required pumping capacity in future. The hydrological model uses daily meteorological observations and forecasts to simulate precipitation, evaporation and percolation to the groundwater. The runoff model describes the water flow from the land area into lakes, and the discharge model describes the water flow from one lake to another.

Meteorological data, such as temperature, precipitation and snow depth are available via Finnish Meteorological Institute (FMI) from the meteorological measurement stations located nearby. The Siilinjärvi snow line water equivalent data is also used. On-site snow depth and density measurements conducted during the project by SYKE and Geological Survey of Finland (GTK), were included in the model. Real-time meteorological forecasts are applied to provide daily hydrological forecasts. Furthermore, weather data from the last 50 years is used to produce a long-term climatological forecast. These observations and weather forecasts are received, read and assimilated automatically into the system.

Water level, discharge and pumping data was retrieved from the mine management system by the mine operator about once a month and sent to SYKE in excel format. Automatic and continuous retrieval of measurement, which would provide more accurate real time forecasts, can be included into the system later. However, the continuous measurement data from the in situ devices installed during this project were automatically retrieved and processed into the modelling system.

Model contains a number of free parameters, which were calibrated against the measurements. Moreover, the WSFS also includes a correction model which corrects model inputs (precipitation and temperature) in order to get hydrological quantities (water equivalent of snow, discharge and water level) to better fit the hydrological observations. As temperature and precipitation observations might not be representative for large areas, this method corrects the model state in order to ensure the best possible initial condition for the model on the forecast day.

Results and operation of the system

As a result, a functional WSFS model was obtained for the Siilinjärvi mining area. It works relatively well for the areas where reliable water level and discharge (or pumping) observations are available, as well as for the natural state lakes. However, some difficulties were met when simulating areas where observations are unreliable or not available. As the model can be operated without direct discharge observations using the regulation schedule (as done in the forecast period), or using a combination of observations and regulation schedule to limit drastic changes in water level, one is still able to obtain sufficiently reasonable results for the areas where reliable observations are missing.

The WSFS mine site model is operated via a web-based interface (Figure 2). It features a clickable map which is used to navigate into different areas and to view their forecasts. All the observations and forecasts are updated automatically, but additional observations can be filled manually via the interface. The simulation is run automatically daily, but can be run also manually, if necessary. Numerical data produced by the system can also be exported into other systems.

Actual operation of the system is controlled using discharge forecasts and regulation schedules. Using the interface operator can set desired values for pumping and discharge from ponds. These discharge forecasts will be then be used for given period of time. Additionally operators can use regulation schedules to specify how much water will be pumped or discharged at certain water levels. The system then automatically adjusts discharges accordingly, and subsequent forecasts will be based on these settings.

Results are presented graphically on the interface web page. Hydrological quantities, such as water level, discharge or pumping, precipitation, evaporation, runoff etc., are all presented as graphs by time for each sub-catchment (in practice for each lake/pond). Example images for water level and pumping of one of the ponds, Vesiallas, are shown in Figure 3. Forecasts for each pond are shown as a coloured band, different colour for each probability fractile. Long term forecast based on historical observations can be used to make probability forecasts for water level and outflows. These results can be used for discharge planning and preparation for various events, such as spring floods.

As the model can be modified for both catchment setup and forecasts, different alternate scenarios can be studied as well. For example, when the mining site is being developed, new reservoirs build and pumping lines installed, their effects to the water balance and discharge can be simulated in the WSFS model. Moreover, weather forecasts can be modified to take account possible climate change scenarios in the future, and to estimate their effect on runoff and discharges. Using different modifications can thus be used to study various, possibly worst case scenarios and addressing possible problems in water management before they appear. This could help minimizing costly risks at the mining site.

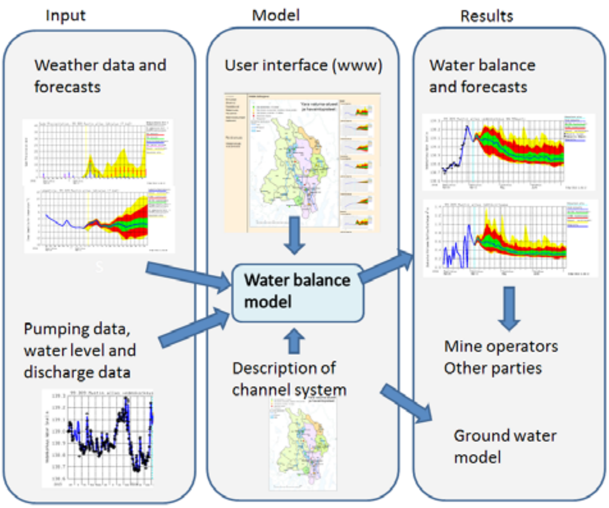

Figure 1 *Schematic diagram for the WSFS model. The model consists of the actual hydrological water balance model and a watershed description (lake and channel system), shown in the middle. It uses hydrological observations (water level, discharge, pumping, etc.) as well as weather observations and forecasts as starting and reference points for simulation. Model then produces forecasts for all the lakes and ponds in the area. Additionally, numerical data can be extracted from the WSFS to be used in other applications and by other parties.*

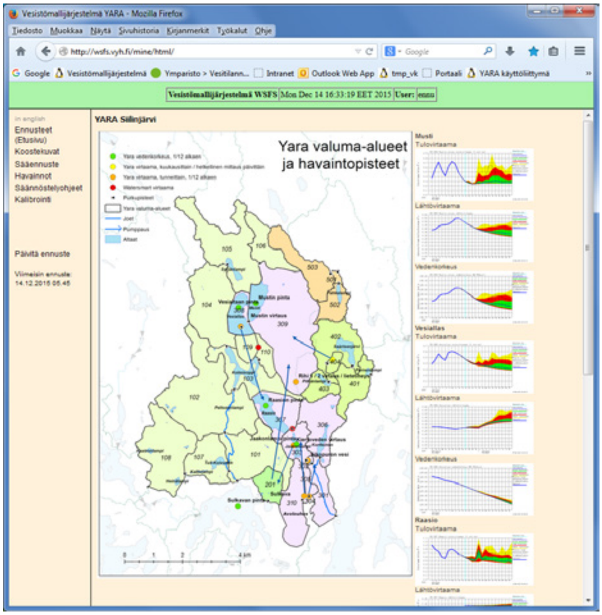

Figure 2 *Web interface for WSFS model. Clickable map shows the watershed description in the mining area and in some surrounding area. Clicking the map opens water balance pictures of the area. Some relevant graphs are on the right side of the map. Menu on the left side bar contains entries for entering observations, regulations schedules and discharge forecasts.*

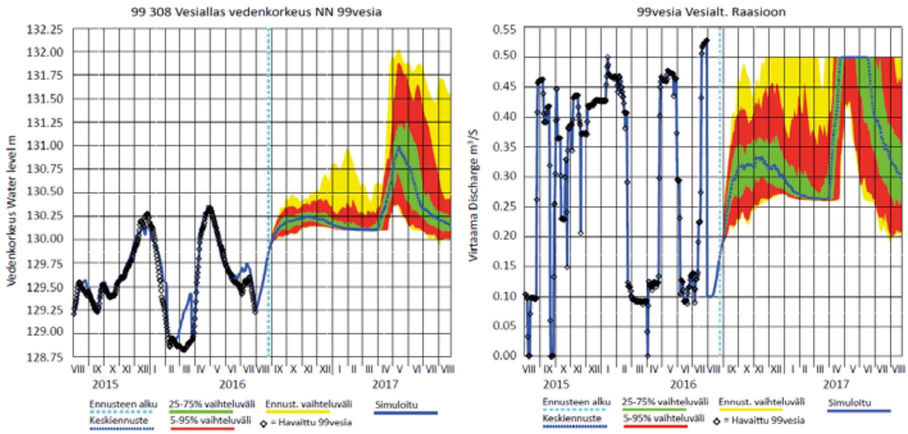

Figure 3 *Water level (on the left) and pumping (on the right) of Vesiallas pond are shown here as an example. Vertical dashed blue line shows the simulation date. Green, red and yellow bands on the right of it shows probability fractiles (50, 70, 90, 100 %) of forecasts.*

Conclusions

A hydrological forecast model for Yara Siilinjärvi mining site was developed for simulating and forecasting water balance in the area. This model aims to provide a tool for mining operators for better water management in the site. It works relatively well in the areas where discharge and water level observations are reliable, but there some difficulties in the areas where observations might be unreliable. Yara is currently using the system and evaluating its usefulness for further development.

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