Guidelines for Mine Water Management

Management of Water Balance in Mining Areas

WaterSmart Seminar 28.8.2015
Report:
Guidelines for mine water management

Target groups:
- Mining companies in Finland to support design and decision-making processes throughout the mine life-cycle starting from early planning stages
- All other relevant parties involved such as consultants, environmental administration, technology providers, research institutes etc.

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Objectives

• Describe current status, needs, and challenges of management of mine water balance
• Identify expected future needs for water management solutions
• Introduce good practices for water balance management:
  • monitoring,
  • water balance modelling,
  • integration of monitoring, modelling and process control
• Present examples of good water management actions implemented in practice
• Describe water management procedures and decisions in different phases of mine life cycle

→ Better implementation of the best practices in mine water management
Background

- Water management is the most challenging stress factor at Finnish mines (Mine stress test report\(^1\)):
  - Mining influences the quality and quantity of waters at mine areas and in the surroundings, and
  - Changes hydrological and topographical circumstances of the area
    - Effects on the surface runoff, groundwater behaviour, soil moisture content and evapotranspiration

- Sites are unique – proper water management requires understanding of the site specific factors
- Water balance management and waste management are linked
- Minimum requirements on water balance monitoring and reporting set in legislation and permits
Proper water balance management is critical to the mine

- Benefits of efficient water management and early planning:
  - Reduction of risks and environmental impacts
  - Cost savings, e.g. optimal storage capacity and diversion of different waters, optimal recycling
  - Social acceptance

- Preparation to extreme situations and changes of water balance during mine life-time
  - Assessment of water balances in mine planning stage
  - Forecasting of hydrological conditions
  - Sufficient monitoring of hydrological conditions, adaptation to potentially risky situations
  - Sufficient knowledge about the quality of water
  - Availability of data from longer periods
  - Dynamic development of monitoring program, water balance modelling and water management
Current needs

- Competence development and practical introduction of water management and modelling tools
- Improved (on-line) monitoring tools for data collection
  - Both water quantity and quality important for optimal collection, treatment and recycling of waters
- User-friendly water balance management tools
  - Quickly updatable, user-friendly interfaces
- Tools which enable integrating the water balances of different operations to one "site-wide-water-balance"
  - How to overcome compatibility challenges
- Integration of water balance management to process control system of the mine
Water balance modelling tools

- Spreadsheet, e.g. Excel based deterministic models quite commonly used but can act as dynamic models with a specialised add-in tool
  - Useful for easy projections, can be rapidly implemented and used to store, display, and check dynamic model inputs, or display and analyse dynamic modelling results
  - Drawbacks: Not transparent, not very well suited for complex modelling, complex models may be difficult to interpret or explain, add-ins needed for uncertainty assessment, errors

- Shift from deterministic methods towards dynamic models, that can be coupled to hydrologic, geochemical, economic, reactive transport and to chemical equilibrium models

- Dynamic modelling simulators: Extendable modelling platforms GoldSim, MATLAB Simulink; prepackaged modelling systems, STELLA, Vensim…
  - More versatile, suitable for complex modelling tasks and complex scenarios, more detailed evaluation

WSFS – Watershed simulation and forecasting system

- WSFS has mainly been used for flood forecasting, realtime monitoring, nutrient load simulation and climate change research
Other modelling tools

Hydrogeological and groundwater flow models
- MODFLOW, MT3DMS, FEFLOW, MODFLOW SURFACT, HydroGeoSphere (HGS), PHREEQC

Equilibrium and chemical models
- HSC Sim, PHAST; PHREEQC, TOUGHREACT, HYDRUS 2D/3D, ChemSheet, OLI
Monitoring

- The water monitoring program depends on the mine characteristics, surrounding grounds and waters, etc.
  - Parameters, such as temperature, pH, EC, Eh, O₂, alkalinity, anions, metals, N, P, etc.
  - Groundwater monitoring – physico-chemical quality and groundwater level, in parallel with local climate measurements
  - Monitoring of surface water and other natural waters – flow measurements, physico-chemical analysis
  - Monitoring of tailings, dams, etc.
  - Weather data – own weather station if possible

- Monitoring tools: on-line, on-site/field and laboratory
  - On-line: flow, water level, pH, T, EC, turbidity, NO₃-N, NH₄-N
  - Field methods: pH, T, EC, turbidity
Monitoring, recommendations

- The monitoring program should progress and develop
  - *Starting from the measurement of baseline water conditions and gathering of meteorological information*
  - *Development on the basis of critical assessment of results from longer periods*

- Continuous monitoring of water flow and water level in basins are recommended as good practices
  - Regular basin inspections are important to confirm the operation of monitoring equipment and water level in basin

- Regular monitoring of surface and groundwaters and water level combined with weather data are important for forecasting of hydrological conditions, to prevent unexpected water situations

- Monitoring results should be available in a database with easy access

- Integration of data from on-line monitoring tools to water management program would be ideal

- Sources: Välisalo, et al. 2014 + several other literature sources
Good practices

- Pro-active approach aiming to solving out the causes behind problems beforehand instead of addressing symptoms
- Water balance management is started from the early planning stages and continues throughout the life-cycle of the mine
  - Needs to be developed and updated along different phases and within phases
    - Development of knowledge, changes of water balance and operations
- The report includes general guidance tables summarising:
  - which topics should be considered in different phases of the mine life-cycle
  - which kind of results and data should be produced, and
  - the most important permits
- Applied case specifically, e.g. different phases may be parallel
### Water management in different mine phases

<table>
<thead>
<tr>
<th>Mine phase</th>
<th>Contents/ Requirements</th>
<th>Results and information for the regulatory units</th>
<th>Permits</th>
</tr>
</thead>
</table>
| Prospecting    | • Gathering information from other regional mining operations                         | • Baseline studies of environment, vegetation, fish, etc. including meteorological data, hydraulic properties to be performed at least 2 yrs before any changes to the environment to help in developing monitoring program | • Reservation notification  
• Prospecting work |}
|                | • Performing environmental baseline study                                              |                                                                                                               |                                             |
|                | • Water availability                                                                    |                                                                                                               |                                             |
| Prefeasibility | • Planning the use of water on a monthly basis implemented in the water model          | • Site-specific water supply implementation to project requirements  
• Preliminary water treatment plan for water user and discharge  
• What-if scenario from model  
• Information for Environmental Impact Assessment  
• Mine closure evaluations | • Natura Assessment |
|                | • Planning water treatment using the baseline study data                                |                                                                                                               |                                             |
|                | • Preliminary mine closure plan                                                         |                                                                                                               |                                             |
| Exploration    | • Sampling of site for mineral analysis without alterations to environment              | • Mineral profile data                                                                                       | • Ore prospecting permit  
• Notification of pilot activities |
|                |                                                                                       |                                                                                                               |                                             |
| Conceptual design | • Planning water monitoring program  
• Water management model setup  
• Catchment descriptions and management plans | • Mine risk class  
• Knowledge of water sufficiency for the mine lifecycle  
• Knowledge on project mine water requirements  
• Water treatment discussions  
• Compilation of the regulatory processes | • Comply with Nature Protection Act  
• Disposal Permits related to Conservation Act |
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| Feasibility                      | • Mine feasibility evaluations and impact assessment from baseline data  
• Daily water management program that includes water quality and quantity monitoring  
• Water sources and demands for mine  
• Discharge quantity and quality as well as costs                                                                                   | • Mine water management program implementing model and monitoring data  
• Mine water plan including water sources, requirements of the mine, water treatment for use and discharge, etc.                                                                 | • Nature Assessment  
• Environmental Impact Assessment  
• Waste management plan  
• Redemption permit for the mining site  
• Dam Safety |
| Investment decision and mine site plan | • Updating plans and models: mine water plan, water management plan, monitoring plan, water treatment plan, etc.  
• Water infrastructure plan and design                                                                                       | • Water use permits  
• Water infrastructure construction  
• Water supply and dam safety approvals                                                                                       | • Land Use & Building Act  
• Water permit  
• Environmental permit  
• Disposal permit  
• Mining permit |
| Construction and commissioning   | • Water infrastructure in detail  
• Water monitoring and reporting  
• Revisions of models and programs                                                                                           | • Water infrastructure (treatment plants, etc.) fulfilled according to permits  
• Reporting of water qualities and quantities according to permits                                                                                                                | • Mining safety permit |
| Operation                        | • Water quality and quantity data collection/monitoring and assessment for revision purposes  
• Water management model revisions according to collected water monitoring data  
• Revisions according to operational needs  
• Update of closure plans                                                                                                         | • Reporting and monitoring of water quality and quantity according to the permits  
• EIA revisions approval                                                                                                         | • Permit revisions and updates |
| Closure, post-closure and after-care | • Water management plans for closure  
• Implementation of water quality and quantity monitoring during closure phases                                                                                       | • Water monitoring and reporting during closure in compliance with permits  
• Rehabilitation plan                                                                                                           | • Permit revisions and updates |
Estimated development of water balance management

<table>
<thead>
<tr>
<th>Present (state of the art) 2014</th>
<th>Intermediate 2020</th>
<th>VISION 2030</th>
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</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
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<tr>
<td>• Software available, few appl. to mines &amp; if applied, only during operation stage</td>
<td>• Dynamic software for environmental waters</td>
<td>Dynamic water management including online quantity &amp; quantity monitoring and chemical equilibrium/reaction modules</td>
</tr>
<tr>
<td>• Monitoring of env. waters not connected to software (dynamic)</td>
<td>• Implementation of chemical equilibrium modules</td>
<td></td>
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<tr>
<td><strong>Products</strong></td>
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<tr>
<td>• Software: GoldSim, Stella...</td>
<td>• Fast lab measurements</td>
<td>• Water management software for mine-specific adaption with user-friendly interface showing water quantity &amp; quality for process, tailings, environment, groundwaters</td>
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<tr>
<td>• Online monitoring sensors for flow, level, temp only</td>
<td>• Larger array of online sensors</td>
<td>• Online water quality sensors</td>
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<tr>
<td>• Onsite measurements of pH, EC, etc</td>
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<td></td>
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<tr>
<td>• Lab. measurement for ions, BOD, COD, etc</td>
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<tr>
<td><strong>Drivers</strong></td>
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<tr>
<td>• Legislation</td>
<td>• Risk minimization</td>
<td>• Safety for the environment</td>
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<tr>
<td>• Public opinion</td>
<td>• Increased water recycling</td>
<td>• Public approval</td>
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<tr>
<td>• Environmental accidents</td>
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<tr>
<td>• Water shortage/surplus</td>
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<tr>
<td><strong>Bottlenecks</strong></td>
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<tr>
<td>• Premine operation data not available</td>
<td>• Online measurements for fast reacting to perturbations</td>
<td>Sensor lifetime/maintenance costs</td>
</tr>
<tr>
<td>• Online monitoring, e.g. sensor lifetime</td>
<td></td>
<td></td>
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<tr>
<td>• Groundwater management</td>
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<tr>
<td>• Information sources required for establishing a site wide water balance is scattered to different stakeholders</td>
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<td></td>
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</tbody>
</table>
Thank you!
TEKNOLOGIASTA TULOSTA