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Simulating the Evolution of End Pit Lake Development During Mine Reclamation

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Summary

Simulating the transient evolution of pit lake development during reclamation activities at open pit mines is important for understanding the ultimate long-term lake level and the period required to reach the stable lake elevation. This presentation will focus on the flow dynamics between the lake and the surrounding groundwater system, although in general the modelled surface water-groundwater interaction could be coupled with geochemical and lake mixing models to also predict the evolution of the lake chemistry. A case study is discussed for an aggregate pit for which the closure plan is currently being developed. The plan includes a large end pit lake and because the pit lake is proximal to a long reach of a major river there are hydraulic connections between the river, the groundwater system and the pit lake. The FEFLOW ifmLAKE plugin was used to simulate the water balance of the lake and consequently the evolution of the lake level, surface area and volume.

Theory / Method / Workflow

Traditional groundwater flow models interact with the surface water regime through boundary conditions applied at the interface between the surface water and groundwater regimes. As a pit lake forms from an originally empty pit, the column of water overlying the groundwater system increases as the lake fills and the footprint over which the lake exists increases. Consequently, where lake boundary conditions need to be applied and the boundary condition values representing the lake depth dynamically change.

The FEFLOW ifmLAKE plugin was used to simulate the filling rate and ultimate pit lake water level. Required inputs for the plugin include:

- The maximum footprint over which the pit lake might develop – defined by the crest of the pit as derived from the end of mining topography
- The topography of the empty pit, used to derive the lake volume-lake level relationship
- Time series of areal fluxes to the lake during the filling period (i.e., precipitation and lake evaporation)
- Time series of any volumetric fluxes representing any external contributions or withdrawals of water to the pit lake during the filling period (for example surface water run off from the pit lake catchment area or flows from nearby surface water sources used to reduce the lake filling time)

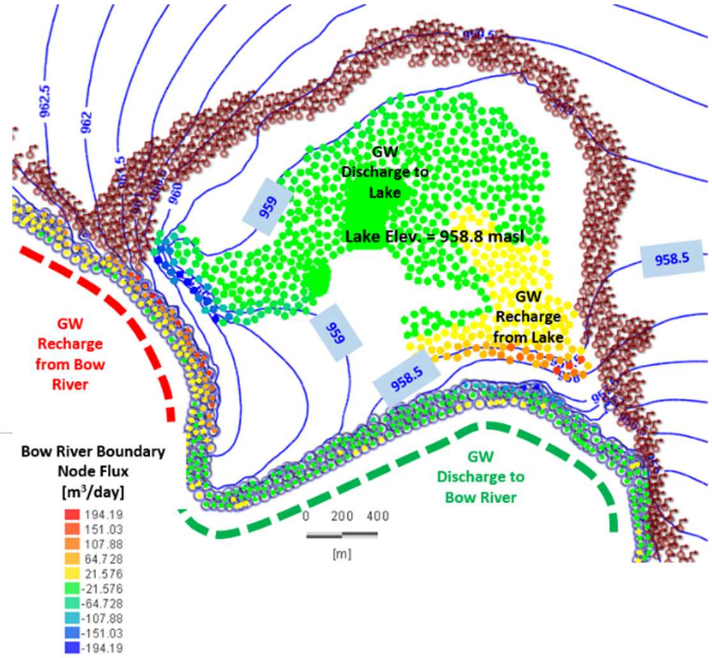
The volume of the lake over time is tracked by computing the water balance for the lake, namely:

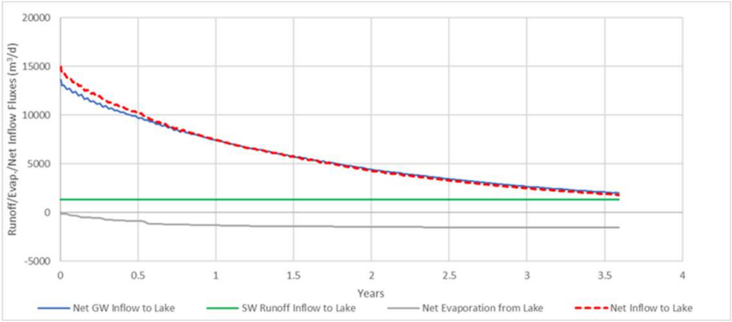
$$V(T + \Delta T) = V(T) + \sum\{F_{areal} \times A(T)\} \times \Delta T + \sum\{F_{vol}\} \times \Delta T$$

where V is the lake volume, A the lake area and the F terms are the areal and volumetric fluxes to the lake. The climatic and external fluxes are defined as inputs and the FEFLOW model calculates the spatially variable groundwater flux between the lake boundary conditions and the groundwater system. The plugin uses the water balance results and the lake volume-lake level relationship to determine the lake level. With this information, the plugin updates the lake surface area, assigns new lake boundary conditions as the lake surface expands and inundates new areas of the pit slopes, as well as updating the lake water level boundary conditions as the lake level rises. Note that because the plugin uses the calculated groundwater fluxes and lake surface area from the current timestep to update the lake water balance for the next timestep, the method is an explicit numerical scheme and as such care must be taken to ensure adequately small timesteps are set during the simulation.

Results, Observations, Conclusions

The left figure below shows the simulated fluxes between the groundwater and the pit after 3-years from the end of operations. Blue and green nodes indicate locations where groundwater is discharge to the pit lake (western side of the model) and yellow and red nodes are locations where lake water is recharging the groundwater system (eastern side of the model). The southern perimeter of the model is the Bow River (upstream reach is on the left side) and shows how river water is recharging the groundwater system along the upstream reach and groundwater is discharging to the river along the downstream reach. The right figure shows the simulated components of the lake water balance over the course of the simulation.





References

https://www.dhigroup.com/download/mike-by-dhi-tools/groundwaterandporousmediatools/ifmlake%20plugin?ref=%7BE38B7F27-20BC-4FCD-BC1A-3D6A1528A5E4%7D