Balancing of interests in polder dewatering: A starring role for an integrated groundwater-surface water model

Bertram Monninkhoff, Volker Clausnitzer, Peter Schätzl

vcl@dhigroup.com
www.dhigroup.com

Toward Sustainable Groundwater in Agriculture
Burlingame/San Francisco, California, 2016

Interaction of surface water and groundwater under highly dynamic conditions

- Rational for coupling ground- and surface water
- Brief description of FEFLOW, MIKE 11 & IfmMIKE11
- Example: Balancing of interests in polder dewatering, a starring role for an integrated groundwater-surface water model
- Outlook

Coupled polder dynamics

FEFLOW, MIKE11, IfmMIKE11 Coupling module

- Flexible mesh generation by finite-element method
- 3D and 2D models
- Unstructured meshes
- Models for groundwater flow
- Saturated (Darcy) flow, incl. phreatic surface
- Variably saturated flow (Richards equation)
- Physical and chemical processes
- Heat transport and/or Reactive multispecies mass transport
- Advection, dispersion, diffusion, sorption
- Density dependence
- Open programming interface
- Coupling to MIKE 11
- Coupling to PHREEQC
- User code
Balancing of interests in polder dewatering

**River boundary condition in FEFLOW**

\[ q_{gw} = -K_g \frac{dh}{dt} = -K_{gw} (h_g - h_r) \]

Horizontal/ lateral infiltration

\[ Q = A \cdot \phi_b (h_r - h_{gw}) \]

Vertical/ surface infiltration

**Vertical/ surface infiltration or T-infiltration?**

- Vertical infiltration: \( W_p = B \)
- Lateral infiltration: \( W_p = 2H \)
- T-infiltration: \( W_p = 2H + B \)

Better representation, but more complicated geometries cannot be represented.

Furthermore, dynamic flooded areas cannot be represented by standard boundaries.

**IfmMIKE11: Integrating FEFLOW and the MIKE11 Hydrodynamic 1D System**

- Dynamic coupling
- Automatic time step control
- Rivers, polders and lowlands
- Depleted rivers and deep groundwater levels
- Wetted area in relation to the real river cross sections
- Mass transport

1D Hydrodynamics with MIKE 11

- Rainfall Run-off
- 1D St. Venant equations
- Forecasting and data assimilation
- Sediment transport
- Ecological modeling
- Stationary / instationary
- Control structures
- Looped networks

In 2016 integrated in MIKE HYDRO River

**Putting the tools to work**
Balancing of interests in polder dewatering, a starring role for an integrated groundwater-surface water model

**Oderbruch (low lands along Odra)**

- Intensive agriculture, low lands dewatering, ecologically important habitats
- Ditches, drains, pumping stations, weirs

**Objective:** Optimize water management to achieve acceptable groundwater levels for various stakeholders and maximize storage

**Conflict analysis**

- Agriculture: has defined monthly groundwater levels for farmland and meadow areas depending on land use
- Nature conservation: The model area is part of European protected areas. Especially migratory birds use the meadows as breeding grounds. A general precondition for this is a relatively high groundwater level. Accordingly, nature conservation protects these special areas and strives to avert a drawdown of the groundwater level.
- Regional water balance: Ecologically-oriented water management aims to reduce the water discharge out of the study area, i.e., to keep as much water as possible within the region. Higher groundwater levels will also reduce the operational cost of the pumping stations.

**Monthly Target Levels**

- Water Authorities
- Stakeholders
Balancing interests in polder dewatering

**Model concept**
- MIKE 11, Surface Water
- DTM
- Monthly Groundwater Recharge
- Coupled System
- FEFLOW

**Calibration**
- Graph showing data analysis for a coupled surface-water and groundwater model.

**Balancing interests on a monthly basis**
- Statistical analyses for Nature conservation and Agriculture
- State in March

**Proposed measures**
- New and adapted weirs
- Resulting groundwater differences in March

**Effect on regional water balance:**
- Overall reduced amount of pumping!

**Summary**
- By...
  - Changing of the target water levels of the pumping stations
  - Demolition of several pumping stations
  - New construction or demolition of weirs
  - Removal of sedimentation in several ditches
  - New construction or removal of several ditches

  ...main objectives for the lowlands along the river Oder could be achieved:
  - Maximum water storage within the area
  - Acceptable groundwater levels for all stakeholders
  - Reduction of energy (pumping) and maintenance costs

  This could only be accomplished by employing a fully coupled surface-water and groundwater model (MIKE11 + FEFLOW).
Subsidence issues

- Subsidence of up to 1 m in a very flat area
- Influence on a very dense dewatering system with many wells and pumping stations and with close interaction of the tidal river Ems
- Coupled FEFLOW - MIKE11 system to achieve water management that reduces the adverse effects on agriculture

Subsidence issues, outlook

Figure 5. (a) Effective stress-dependent porosity functions used in the recovery analysis. Solid lines illustrate compression due to pumping and dashed lines illustrate expansion during recovery. (b) Simplified recovery in porous (dashed line) and impermeable (solid line) as a function of elevation. Note that curves of change in porosity and consolidation are the product of groundwater pumping match curves of recovery in porous and expansion for an elastic aquifer system.

Irrigation on demand using MIKE SHE

- CATCHMENT HYDROLOGY - modern catchment management requires understanding of the dynamic, spatial distribution of surface water and groundwater flows
- AGRICULTURE - ET drives the largest global water user, and excess nutrients are the largest global threat to water quality
- CLIMATE CHANGE - integrated water resources management is sensitive to climate change induced feedbacks between rainfall, snow melt, and ET
- WETLANDS - a wetland is the physical expression of groundwater–surface water exchange, yet many wetlands are surface water controlled and sensitive to riparian ET

Bidirectional coupling module between FEFLOW & MIKE SHE

Irrigation on demand using MIKE SHE

- 1st day: Water
- 2nd day: Corn
- 3rd day: Sand
- 4th day: Silt

Balancing of interests in polder dewatering

Balancing of interests in polder dewatering

Balancing of interests in polder dewatering
Conclusions and Outlook

- The coupling between MIKE11 and FEFLOW is a well-working tool, offering integrated surface- and groundwater analysis for operational use.
- The system is ready to use and was employed successfully in various projects.
- Applications include polder management, groundwater-induced flooding, mine-water management, climate-change effects on minimum river discharges, and river restoration.
- Extensions of the system will involve irrigation management (coupling to MIKE SHE) and subsidence (implementation within FEFLOW).
- Stakeholder participation will increase the acceptance of the necessary changes within a catchment.