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

DHI WASY

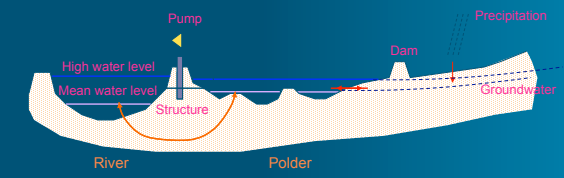
Interaction of surface water and groundwater under highly dynamic conditions

DHI WASY

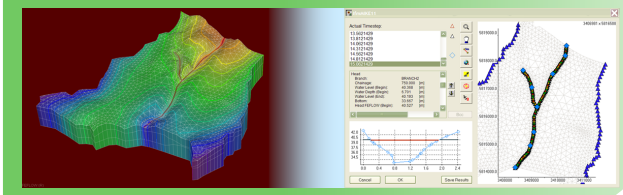
- Rational for coupling ground- and surface water
- Brief description of FEFLOW, MIKE 11 & IfmMIKE11
- Example: Balancing of interests in polder dewatering, a starring role for an integrated groundwater-surface water model
- Outlook

Coupled polder dynamics

DHI WASY



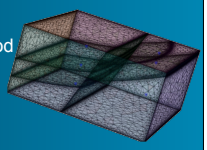
FEFLOW, MIKE11, IfmMIKE11 Coupling module



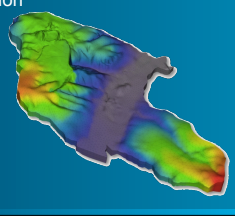
DHI WASY

FEFLOW Groundwater simulator

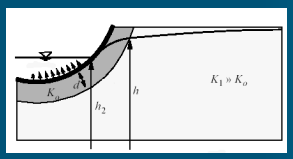
DHI WASY

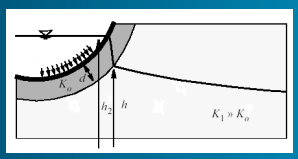


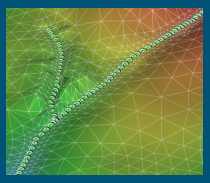
- Flexible mesh generation by finite-element method
  - 3D and 2D models
  - Unstructured meshes
- Models for groundwater flow
  - Saturated (*Darcy*) flow, incl. phreatic surface
  - Variably saturated flow (*Richards* equation)
- Physical and chemical processes
  - Heat transport and/or Reactive multispecies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



River boundary condition in FEFLOW







$$q_{n_h} \approx -K_o \frac{\Delta h}{\Delta l} = -K_o \frac{h_2 - h}{d}$$

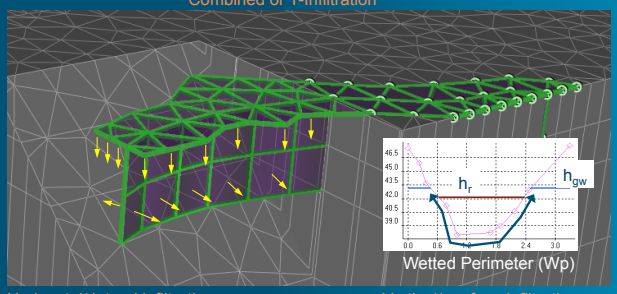
Transfer rate $\Phi_h \approx \frac{K_o}{d}$ in $[d^{-1}]$

$$Q = A * \phi_h (h_r - h_{gw})$$

Balancing of interests in polder dewatering

River boundary condition in FEFLOW

Combined or T-Infiltration



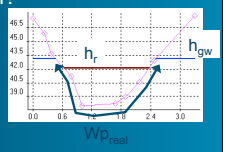
Horizontal/ lateral infiltration

Vertical/ surface infiltration

Balancing of interests in polder dewatering

Vertical/ surface infiltration or T-infiltration?

$$Q = Wp * L_{rep} * \phi_h (h_r - h_{gw})$$



Vertical infiltration

Wp = B

Lateral infiltration

Wp = 2*H

T-infiltration

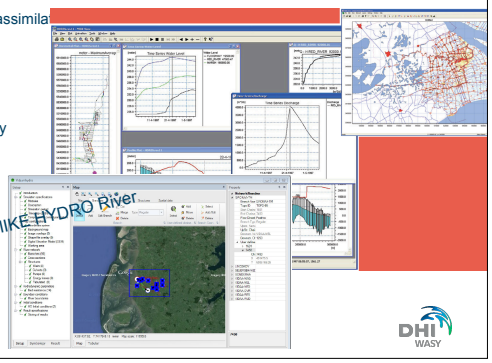
Wp = 2*H + B

Better representation, but more complicated geometries can also not be represented.
Furthermore, dynamic flooded AREAS cannot be represented by standard boundaries

Balancing of interests in polder dewatering

1D Hydrodynamics with MIKE 11

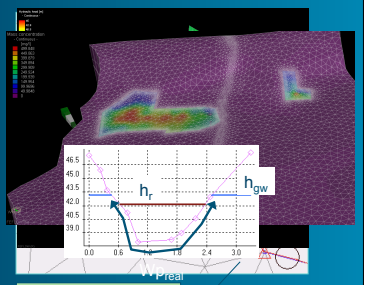
- Rainfall Run-off
- 1D St. Venant equations
- Forecasting and data assimila
- Sediment transport
- Ecological modeling
- Stationary / instationary
- Control structures
- Looped networks



in 2016 integrated in MIKE HYDRO River

IfmMIKE11: Integrating FEFLOW and the MIKE11 Hydrodynamic 1D System

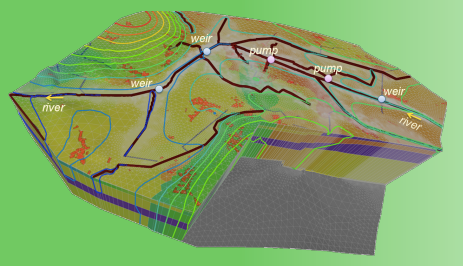
- Dynamic coupling
- Automatic time step control
- Rivers, polders and lowlands
- Depleted rivers and deep groundwater levels
- Wetted area in relation to the real river cross sections
- Mass transport



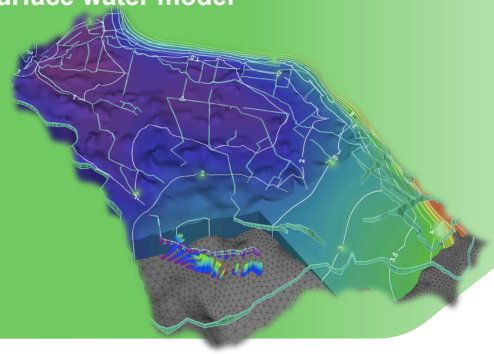
FEFLOW Element

Balancing of interests in polder dewatering

Putting the tools to work

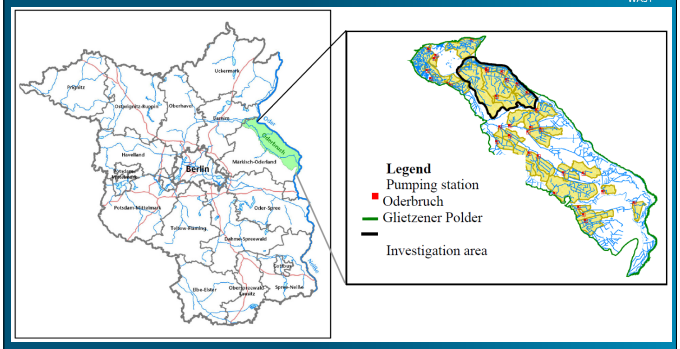


Balancing of interests in polder dewatering, a starring role for an integrated groundwater-surface water model



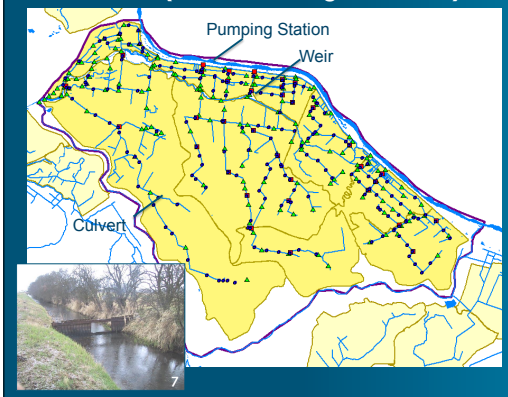
© DHI-WASY

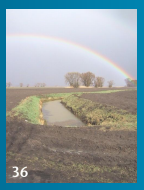
Oderbruch (low lands along Odra)



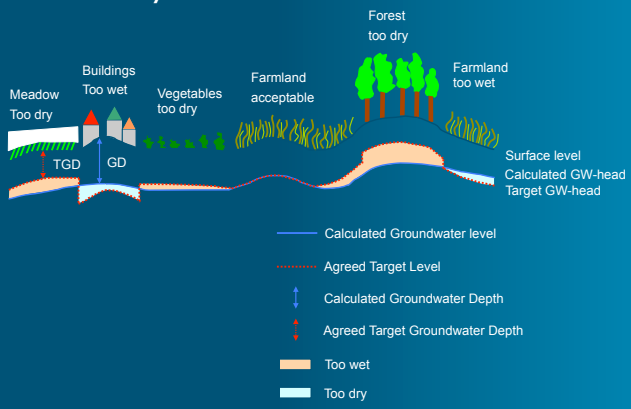
- Intensive agriculture, low lands dewatering, ecologically important habitats
- Ditches, drains, pumping stations, weirs

Oderbruch (lowlands along river Oder)

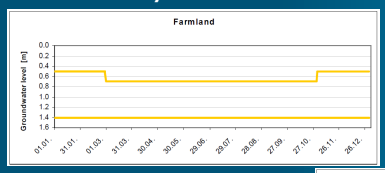




Conflict analysis

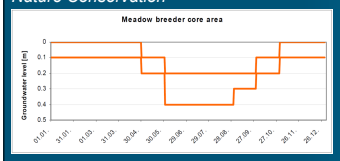


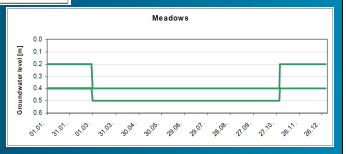
Conflict analysis



Agriculture

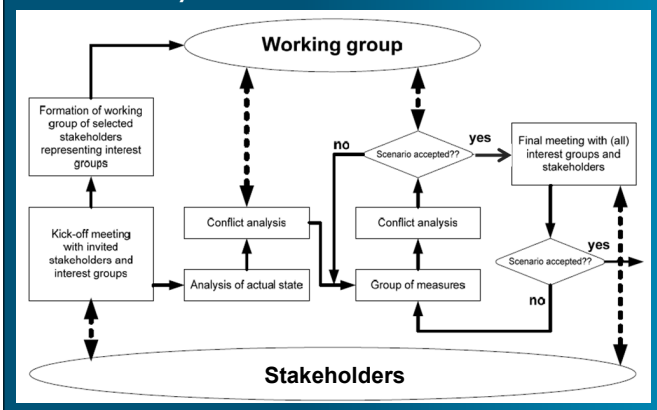
Nature Conservation



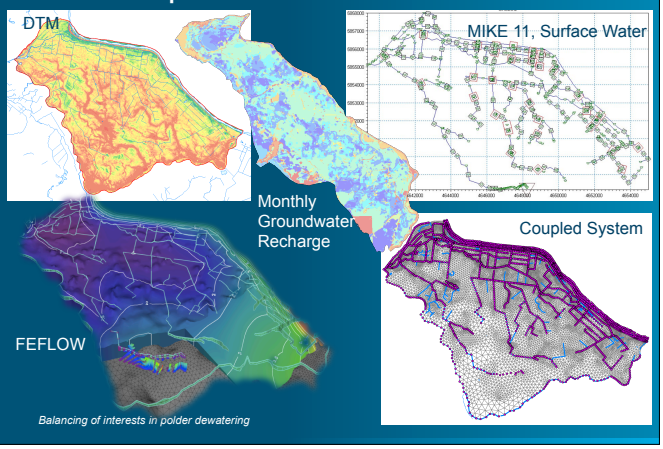


Monthly Target Levels

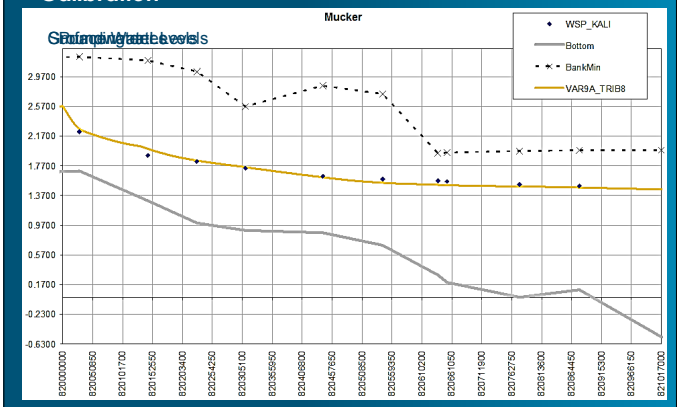
Conflict analysis



Model concept

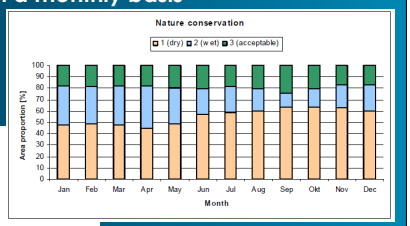


Calibration

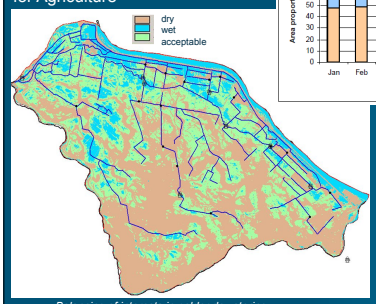


Balancing interests on a monthly basis

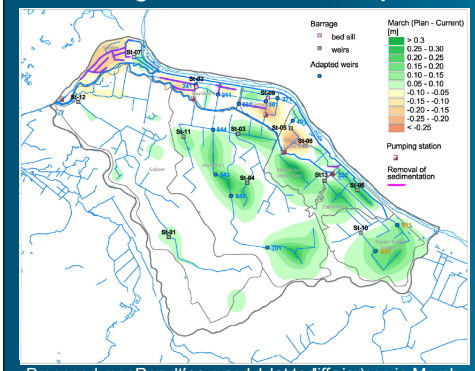
Statistical analyses for Nature conservation



State in March for Agriculture

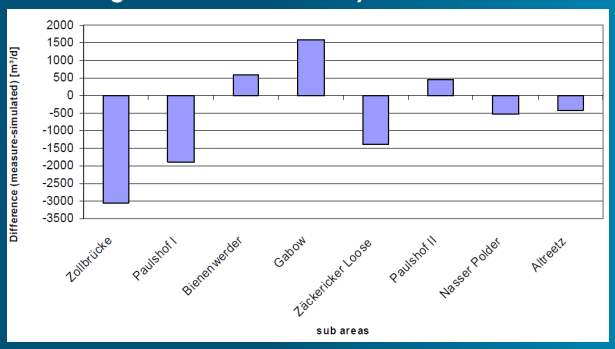


Balancing interests on a monthly basis



Proposed measures (groundwater differences in March

Balancing interests on a monthly basis



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:

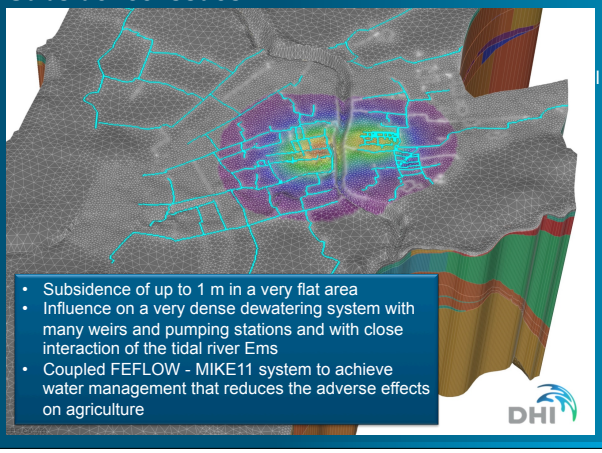
- Maximum water storage within the area
- Acceptable groundwater levels for all stakeholders
- Reduction of energy (pumping) and maintenance costs

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

Outlook

© kurter al, 2015

Subsidence issues



- Subsidence of up to 1 m in a very flat area
- Influence on a very dense dewatering system with many weirs 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

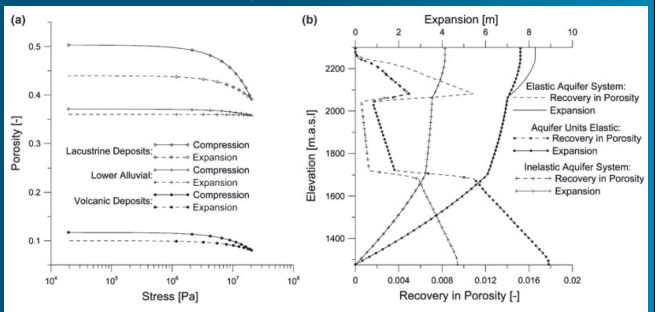
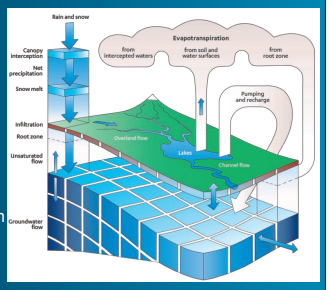


Figure 5. (a) Effective stress-dependent porosity functions used in the recovery analysis. Solid lines illustrate compression due to pumping and dashed lines illustrate expansion during recovery. (b) Simulated recovery in porosity (dashed lines) and expansion (solid lines) as a function of elevation. Note that curves of change in porosity and consolidation due to 100 years of groundwater pumping match curves of recovery in porosity and expansion for an elastic aquifer system.

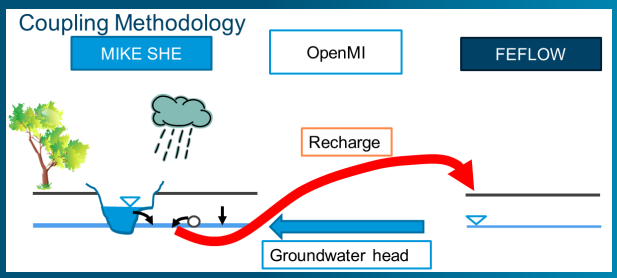
(Preisig et al, 2013)

Irrigation on demand using MIKE SHE

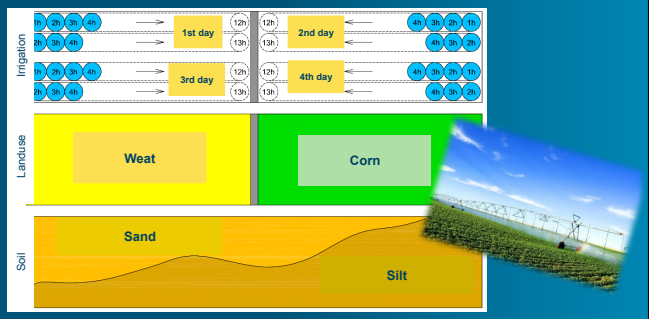
- CATCHMENT HYDROLOGY - modern catchment management requires understanding of the dynamic, spatial distribution of surface water and groundwater flows
- AGRICULTURE - ET drives the largest global water user, and excess nutrients are the largest global threat to water quality
- CLIMATE CHANGE - integrated 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



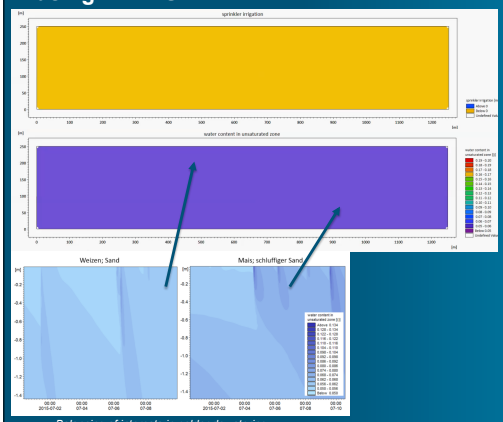
Bidirectional coupling module between FEFLOW & MIKE SHE



Irrigation on demand using MIKE SHE



Irrigation on demand using MIKE SHE



Irrigation progress

Saturation soil (%)

Depth profiles
Saturation soil

Facilitating stakeholder participation with MIKE HYDRO BASIN

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.

Thank you for your attention

Bertram Monninkhoff, Volker Clausnitzer, Peter Schätzl

vcl@dhigroup.com
www.dhigroup.com