Risk analysis for high groundwater levels focussed on residential buildings in Dresden, Germany

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Background

In several cities around the world, problems with rising groundwater levels were reported, but up to now, losses caused by high groundwater levels have been neglected in flood loss assessment studies and risk analysis. Reliable loss models are also necessary to evaluate the cost-effectiveness of mitigating measures like groundwater withdrawal and drainage.

Objective

The city of Dresden in Germany has initiated the research project "MULTISURE - Development of Multisequential Mitigation Strategies for Urban Areas with Risk of Groundwater Flooding" which aims at the development of assessment methods for the hazard, the damage potential and the risk due to interactions of riverine and groundwater flooding.
The aim was the adaptation of the Flood Loss Estimation MOdel for the private sector – FLEMOps for high groundwater levels and its validation on the micro- and meso-scale. FLEMOps is based on empirical flood loss data which has been collected after the flood in the Elbe- and Danube-catchments in 2002. It is a new, innovative, rule based model which takes into account several impact factors besides the water depth, such as building type and quality as well as contamination and precaution. It is applicable on the micro-scale, i.e. single buildings, and on the meso-scale, i.e. land use units (Fig. 1).

Concept and input data

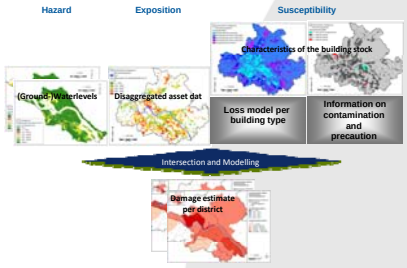

Figure 1 Sketch of the meso-scale validation and model application including necessary input data

Damage model development

The micro-scale model (Fig. 2 & Table 1) was based on groundwater flood damage data collected after the 2002 flood in Germany (Kreibich & Thieken 2008). The model was scaled to the meso-scale to enable a regional application on basis of land use units (Figure 1 & Table 2).

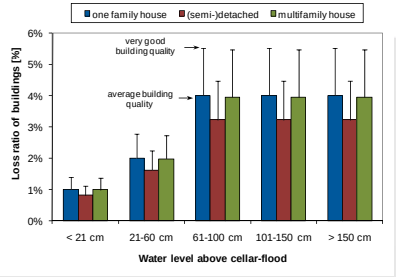

Figure 2 FLEMOps for groundwater flooding – first model stage

Table 1 FLEMOps+ second model stage using scaling factors

		Precaution		
		no	good	very good
Contamination	no	1.09	0.70	0.55
	medium	1.34	0.86	0.68
	heavy	1.34	0.86	0.68

Table 2 Mean composition of residential buildings in 5 clusters (EFH: one-family home, RDH: (semi-)detached house, MFH: multifamily house)

Cluster	Share EFH [%]	Share RDH [%]	Share MFH [%]	Description
1	12.00	5.13	82.87	Dominated by multifamily houses
2	31.35	24.58	44.07	Mixed (high share of MFH)
3	37.51	46.19	16.30	Mixed (high share of RDH)
4	68.51	21.43	10.05	Mixed (high share of EFH)
5	92.25	4.81	2.94	Dominated by one-family houses

Validation

FLEMOps for groundwater flood damage was successfully validated on the micro-scale (Table 3) using data from a survey in Dresden (KREIBICH et al. 2009). The meso-scale validation (Table 4 & Fig. 3) based on official flood damage data of the 2002 flood in Dresden points to a very good suitability of the meso-scale approach.

Table 3 Micro-scale validation: Analysis of confidence interval and error statistics for the estimation of damage ratios for buildings

Data for validation	Confidence interval	
Mean loss ratio	2.5% - percentile	97.5% - percentile
0.02900	0.00798	0.05432
Estimation	**FLEMOps**	**FLEMOps+**
Mean loss ratio	0.02750	0.02124
Within confidence interval	yes	yes
Mean bias error (MBE)	-0.00009	-0.00020
Mean absolute error (MAE)	0.00042	0.00042
Root mean square error (RMSE)	0.00428	0.00478

Table 4 Comparison of official and modelled damage data of residential buildings due to the 2002 flood in Dresden in million €

	FLEMOps	FLEMOps+	BEAK CONSULTANTS 2006	KORNDÖRFER 2006	SAB 2005
Groundwater flood damage	62.8	44.0	71.5		
Riverine flood damage	276.6	254.5			
Total flood damage	339.4	298.4		304.0	239.8

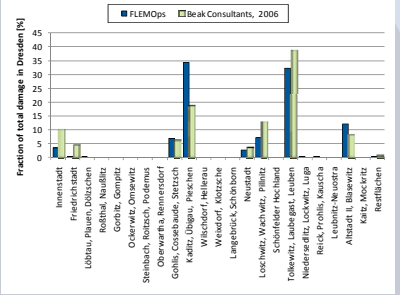

Figure 3 Relative comparison of modelled damage with FLEMOps and of BEAK CONSULTANTS (2006) due to groundwater flooding during and after the 2002 flood: Fraction of groundwater flood damage per district in Dresden

Application and risk analysis

Table 5 Groundwater flood damage to residential buildings in Dresden modelled with FLEMOps and FLEMOps+ for the valid area of different groundwater flood scenarios (boundary conditions: summer (So)/winter (Wi)/not seasonal (nS); with/without consideration of flood control measures (HWSM)).

	HQ100 So oHWSM	HQ100 So mHWSM	HQ100 Wi oHWSM	HQ100 Wi mHWSM	HQ100 nS oHWSM	HQ100 nS mHWSM
FLEMOps	5.3	9.0	44.7	30.7	61.7	36.4
FLEMOps+	2.9	5.0	24.6	16.9	34.0	20.0

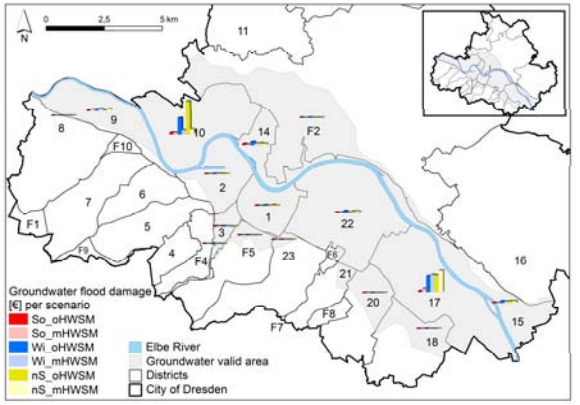

Figure 4 Groundwater flood damage to residential buildings in Dresden modelled with FLEMOps on basis of different groundwater flood scenarios

Conclusions

The multi-factorial flood loss model FLEMOps was further developed for groundwater flood damage. The model was successfully validated on the micro- and meso-scale using survey data as well as official damage data. Therefore, particularly with meso-scale FLEMOps a model is developed, which is able to provide reliable information on groundwater flood damage for large regions with relatively little effort. Thus, FLEMOps is an efficient tool for groundwater flood risk analysis, as shown in Dresden. The meso-scale version of the model was applied to six groundwater flood scenarios which are related to a 100 year flood of the Elbe in Dresden (Table 5 & Fig. 4). The estimated losses between 3 and 62 million Euros stress the relevance of the risk due to high groundwater levels.

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