XXXVIII IAH Congress

Groundwater Quality Sustainability

Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

IAH 2010 Krakow

abstract id: **252**

topic: **1**
Groundwater quality sustainability

1.2
Groundwater vulnerability and quality standards

title: **Groundwater nitrate vulnerability assessment using process-based models and weights-of-evidence technique – Lower Savinja Valley case study (Slovenia)**

author(s): **Jože Uhan**
Environmental Agency of the Republic of Slovenia, Slovenia, joze.uhan@gov.si

Goran Vižintin
University of Ljubljana, Faculty of Natural Sciences and Engineering, Slovenia, goran.vizintin@guest.arnes.si

Jožef Pezdič
RO GEORIS, Slovenia, joze.pezdic@georis.si

keywords: groundwater nitrate vulnerability, weights-of-evidence, Lower Savinja Valley (Slovenia)

Groundwater is the most important and valuable source of drinking water in Slovenia, and alluvial aquifers contribute a vital part to the dynamic reserves of all Slovene groundwater. More than one third of the alluvial groundwater in Slovenia has poor chemical status, most frequently due to a high concentration of nitrate. The Lower Savinja Valley alluvial aquifer (79 km^2) in central part of Slovenia (Fig. 1) with important regional water resources and high pollution pressures due to agriculture (50.4% of the area) and urbanization (34.0% of the area) was selected as a case study for experimental field-verified groundwater nitrate vulnerability mapping. A spatially explicit identification of the potentially vulnerable priority areas within groundwater bodies is being required for cost-effective measures and monitoring planning.

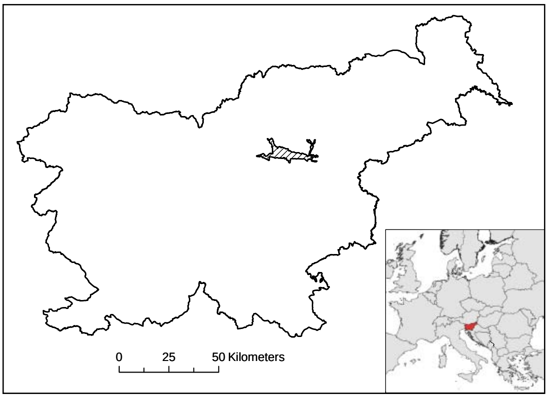

Figure 1. Location of the Savinja Valley groundwater body in Slovenia.

The shallow Lower Savinja Valley unconfined aquifer system consists of high permeable Holocene and middle to low permeable Pleistocene gravel and sand with a maximum thickness of about 30 meters, mainly covered by shallow eutric fluvisoils or variously deep eutric cambisoil. The hydrogeological parameters, e.g., the depth to the groundwater, hydrological role of the topographic slope etc., usually used in different point count schemes are in the case of the lowland aquifer and shallow groundwater spatially very uniform with low variability. Furthermore, the parametric point count methods are generally not able to illustrate and analyze important physical processes and validation of the results is difficult and expensive. Instead of a parametric point count scheme, we experimentally used the Arc-WofE extension for weights-of-evidence modeling (Kemp et al., 1999), considering recent groundwater vulnerability studies from the United States (Baker et al., 2007) and from northern Italy (Masetti et al., 2007).

All measurement locations with a concentration higher than the threshold value of 20 mg NO_3^- per litre of groundwater have been considered as training points (179) and the three process-based model generalized output layers of long-term groundwater recharge (Andjelov, 2009), groundwater flow velocity (Vižintin, Uhan, 1999) and nitrogen load in seepage water served as evidential themes. The technique is based on the Bayesian idea of the phenomena occurrences probability before (prior probability) and after consideration of any evidential themes (posterior probability), which were measured by positive and negative weights as an indication of the association between a phenomena and a prediction pattern. The response theme values describe the relative probability that a 100×100 metre spatial unit will have a groundwater nitrate concentration higher than the training points threshold values with regard to prior probability value 0.0018 (Figure 2).

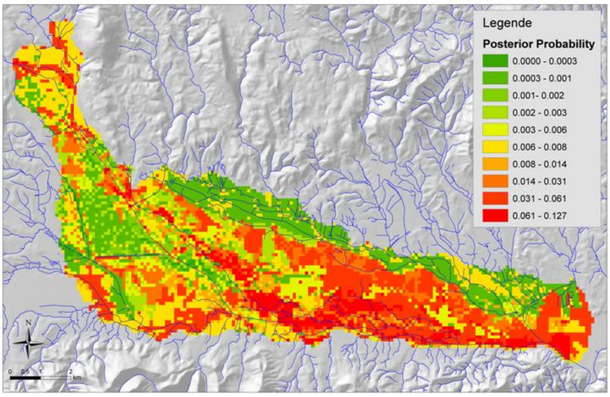

Figure 2. Posterior probability map of groundwater nitrate occurrence in the Lower Savinja Valley aquifer.

The lowest probability of groundwater nitrate occurrence is in the parts of the Lower Savinja Valley aquifer, which are known as anoxic condition areas with very likely denitrification processes. Due to findings of anoxic conditions and the indication of a denitrification process in some parts of the study area, a separate dissolved oxygen response theme was generated (Fig. 3). The upper quartile of the dissolved oxygen data from the same wells as the nitrate concentration data for the nitrogen response theme served as the training points theme. A dissolved oxygen response was compared with the existing nitrogen response theme and used the Kappa (κ) coefficient (Jenness, Wynne, 2007) as a measure of spatial agreement between different themes. The Kappa coefficient calculated for the Lower Savinja Valley groundwater nitrate and for the dissolved oxygen response theme (κ=0.87) indicates sustainable agreement of the themes and verifies that dissolved oxygen is a good predictor of nitrate vulnerability.

The confidence values of the groundwater nitrate model area, as a ratio of posterior probability to its estimated standard deviation, ranged from 1.80 to 3.53 (Tab. 1). These values inicated that the confidence level was above 90% for the majority of the model area (Fig. 4). Area of lower confidence corresponde with area that lack training points.

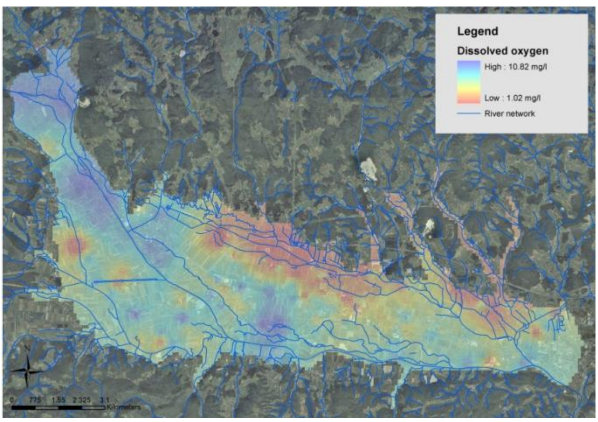

Figure 3. Distribution of dissolved oxygen in groundwater of the Lower Savinja Valley aquifer.

The weights-of-evidence model result map was tested for conditional independence. The actual training sites used in the model vesus the predicted points from the response theme is the confidental independance ratio. Calculated confidental independance ratio for Lower Savinja Valley aquifer model is still within the range 1.00±0.15 (Rainers, 2001) and used evidential themes were considered independent of each other.

Table 1. Calculated weights (W1 in W2) for each evidential theme with associated contrast and confidence values.

Evidental Theme	W1	W2	Contrast	Confidence
Long-term groundwater recharge	0.485	–0.704	1.189	1.800
Nitrogen load in seepage water	0.297	–0.465	0.762	2.400
Groundwater flow velocity	0.900	–0.572	1.472	3.534

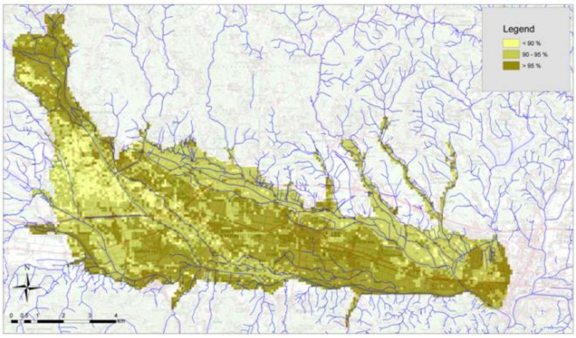

Figure 4. Distribution of confidence values for groundwater nitrate response theme in the Lower Savinja Valley aquifer.

The weights-of-evidence model results very clearly indicate regional groundwater nitrate distribution and enable spatial prediction of the probability for increased groundwater nitrate concentration in Lower Savinja Valley aquifer in order to plan the groundwater nitrate reduction measures and optimize the programme for monitoring the effects of these measures.

ACKNOWLEDGEMENTS

The authors would like to deeply thank Vlado Savić and Janja Turšič from the Environmental Agency of the Republic of Slovenia, who provided us with useful and helpful assistance in field measurements and laboratory work.

REFERENCES

Andjelov M., 2009: *Modeliranje napajanja vodonosnikov za oceno količinskega stanja podzemnih voda v Sloveniji v letu 2006 (Groundwater recharge modelling for 2006 groundwater quantitative status assessment in Slovenia).* Proceedings of 20. Mišičev vodarski dan, Maribor, pp. 126–130 (in Slovenian).

Baker A.E., Wood A.R., Cichon J.R., 2007: *The Marion County Aquifer Vulnerability assessment.* Marion County Project No. SS06-01, 42 p.

Jenness J., Wynne J.J., 2007: *Cohens Kappa and classification table metrics 2.1: An ArcView extension for accuracy assessment of spatially explicit models.* http://www.jennessent.com/arcview/kappa_stats.htm.

Kemp L.D., Bonham-Carter G.F., Raines G.L., 1999: *Arc-WofE: Arcview extension for weights of evidence mapping.* http://www.ige.unicamp.br/wofe.

Masetti M., Poli S., Sterlacchini S., 2007: *The Use of the Weights-of-Evidence Modeling Technique to Estimate the Vulnerability of Groundwater to Nitrate Contamination.* Natural Resources Research, Vol. 16, No. 2, pp. 109–119.

Raines G.L., 2006: *Resource materials for a GIS spatial analysis course.* USGS Open File Report 01-221, 122 p.

Vižintin G., Uhan J., 1999: *Uporaba hidrološkega GIS-a pri modeliranju toka podzemnih voda v Spodnji Savinjski dolini (The hydrological application of GIS for groundwater flow modeling in Lower Savinja Valley).* Proceedings of 14. posvetovanje slovenskih geologov, Geološki zbornik, 14, Ljubljana, pp. 54–55 (in Slovenian).

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD

ISSN 0208-6336

ISBN 978-83-226-1979-0