PROLINE-CE

WORKPACKAGE T2, ACTIVITY T2.3

IMPLEMENTATION OF BEST PRACTICES FOR WATER PROTECTION IN PILOT ACTIONS

D.T2.3.1 EVALUATION REPORTS FOR EACH PILOT ACTION

PILOT ACTION: PA2.5 Neufahrn b. Freising

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1. Introduction

Best management practices (hereinafter BMPs) for drinking water protection and management derived from T1 were reviewed and relevant BMPs were selected for particular pilot action. Implementation status of BMPs was verified in Pilot Actions (T2); in case of lacks identified, possibilities of improvement and implementation were also assessed. Drinking water protection and management and best practices are strategically implemented in the pilot actions, in order to achieve a function-oriented land-use based spatial management for water protection at the operational level. Measures and actions were analysed and proposed concerning mitigation of extremes and achieving a sustainable drinking water level. PROLINE-CE pilot actions reflect the broad range of possible conflicts regarding drinking water protection, such as: forest ecosystem service function; land-use planning conflicts; flooding issues; impact of climate change and land-use changes; demonstration of effectiveness of measures including ecosystem services and economic efficiency.

Review of main land use conflicts and BMPs on Pilot Action level has already been done in Pilot Action BMPs reports, which were a basis for *D.T2.1.2 Transnational case review of best management practices in pilot actions*. Description of natural characteristics of Pilot Site is presented in *D.T.1.4 Descriptive documentation of pilot actions and related issues*.

Activities within Pilot Action are described in *D.T2.2.2 Partner-specific Pilot Action documentation report*.

The Deliverable *D.T2.3.1 Evaluation reports for each pilot action* presents an evaluation of actual implementation and thematic interpretation of tested management practices as well as their acceptance among stakeholders and experts is carried out for pilot action PA2.5 Neufahrn b. Freising.

2. Evaluation of BMPs in Pilot Action

2.1. Implementation of BMPs

2.1.1. Implementation of a continuous monitoring program in both, surface water and groundwater

In order to understand the impact of land use change on the pilot area of Neufahrn bei Freising, we first analysed the available groundwater quantity and quality data (see deliverable D.T.2.2.4). Both water level time series as well water quality time series highlighted important temporal gaps, as shown for the NO_{3^-} and K concentrations as measured in Quaternary aquifer water (Figure 1). Incompleteness of the dataset increases significantly the analysis of the collected data and in particular the interpretation of land use changes on water quality and quantity.

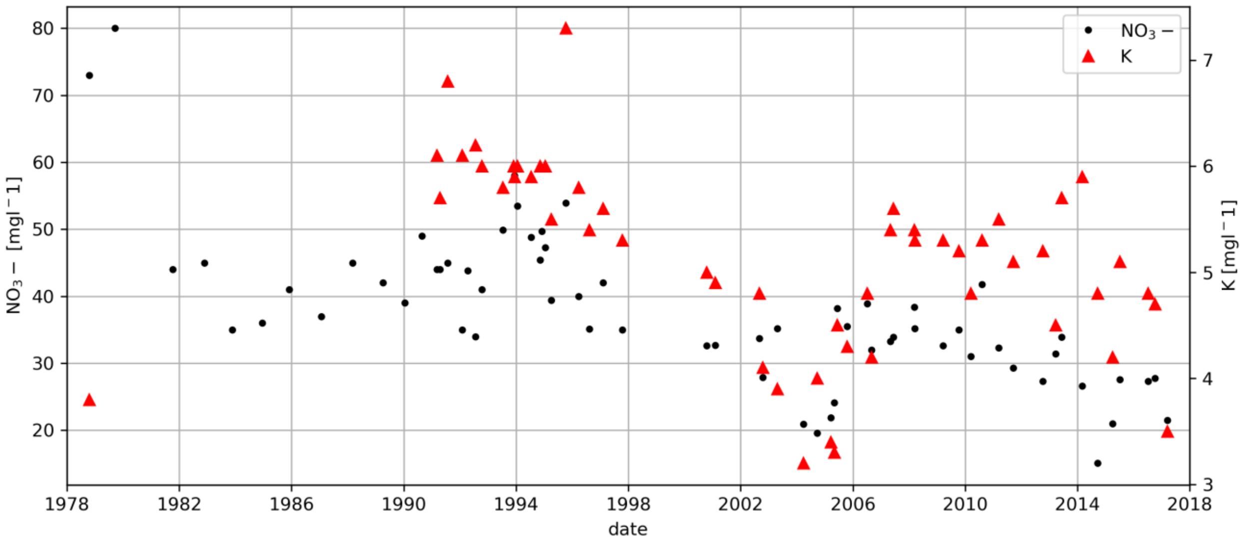

Figure 1: Nitrate and Potassium time series.

The main advantage of field measurements is the characterization of the site under undisturbed conditions, which can be useful, for instance, for real time detection of water quality threats and the fine temporal resolution of the collected information. In the field, many important physical, chemical and biological parameters can be performed through several instruments. Some of the most important parameters are discussed in the following.

In the pilot action, we recently installed a multi parametric probe which is able to monitor in situ and continuously temperature, electrical conductivity, pH, nitrate, dissolved oxygen and turbidity (Figure 2).

Temperature

Temperature is a very important physical parameter when water quality is assessed, for example reaction rates are influenced by temperature. Its assessment is important for water quality by itself as indicator of ongoing exothermic reactions or infiltration of water from different sources in the aquifer (e.g., river water infiltration), but it is also essential because of its effects on some other parameters (e.g., electrical conductivity, salinity, pH, water density, oxidation reduction potential, among others).

Temperature instruments are based on a thermistor. The thermistor is a resistor, which depends on temperature. Once the signal produced by the temperature variation is received in the resistor, an algorithm is used to convert the resistance in a corresponding temperature.

Figure 2: Installed multi-parametric probe in the Neufahrn bei Freising pilot area.

Electrical Conductivity

Electrical conductivity is a parameter which indicates the ability of the water to transmit an electrical current and, indirectly, can be considered as measurement of salts content in water. Tracers and ions can increase the conductivity of water. Fast or abrupt changes may indicate the presence of contaminants (e.g., waste water) in the water body coming from a pollution source upstream.

The common electrical conductivity meter measures the electrical resistance through a potentiometric method at four electrodes of pure nickel or platinum metal. The basic principle is the measurement of the potential between the two pairs of electrodes (two of the electrodes have a controlled current and the other two measure the voltage drop).

current/voltage~ conductivity

It is better to report a conductivity at a particular temperature. Therefore, we defined specific conductivity as the measured conductivity after a normalization at 25 ℃:

Specific conductivity [25℃]=Conductivity/(1+TC×(T-25)

Where,

T = temperature

TC = temperature coefficient of 1.91% (TC = 0.0191)

Conductivity = measured (initial) conductivity

Turbidity

Turbidity designates the clarity and content of suspended particles in water. It is and parameter of water quality based on the total suspended solids.

Basically, the instruments to measure turbidity in situ are based on the capacity particles suspended in a liquid to scatter the light. The detector is a photodiode with high sensitivity which receives the light coming from a light-emitting diode (LED).

Dissolved oxygen

As its name indicates, dissolved oxygen, DO, is a measurement of the amount of oxygen in a water body. DO is considered one of the most significant parameters to evaluate water quality. For example, depletion on DO could show us the presence of organic pollutants which are undergoing aerobic degradation. Two of the most common methods to measure DO are the amperometric and the optical measurement. The first is based on Clark cells where an electrical current is generated according to the partial pressure of dissolved oxygen. The second technology, applied in Neufahrn bei Freising, is based on the duration of fluorescence generated from a luminophore and measured by a photodiode. The presence of DO reduces the time duration and the intensity of the fluorescence.

pH

The pH value is a measurement of how acid or alkaline is an aqueous solution on a scale of 0 to 14 (pH scale is logarithmic). To be more precise, pH is a measure of hydrogen ion concentration. Several sources can affect the pH in a water body, including natural factors (e.g., calcium carbonate content, photosynthesis) and human factors (e.g., acid rain, point source pollution).

One accurate way to determine the pH value is by electrochemical measurements. This method consists on a pH electrode that is sensitive to hydrogen ions and generates a potential as function of the pH in the surrounding areas.

Nitrogen

The main sources of nitrogen in water are the agricultural activities which release sewages and fertilizers. But, in the same way of phosphorus, nitrogen may can be found naturally. Excessive amounts of nitrogen (e.g., too much nitrate) can cause exceedance of the limit concentrations.

Nitrate sensors are based on silver or silver chloride wire electrodes in a special solution. A polymer separates the solution and the sampled medium. The membrane interacts with nitrate ions selectively, producing a potential which depends on the amount of nitrate. The Nernst equation is used to relate the potential of the electrochemical reaction and the observed voltage.

2.1.2. Development of a hydrological model to find site specific solutions

As outlined in deliverable DT2.2.2, public engagement should take place already at early steps of the decision process. The development of action plans for the implementation of protection plans should be carried out in close cooperation with land owners that are directly affected by future regulations in the delineated protection zones. A gap that was identified during the stakeholder meeting (deliverable D.T1.3.2) and during the online survey was the lack of technical and scientific expertise of several stakeholders. Most of the conclusions derived by the stakeholders and their proposal for sustainable land use management solutions were mainly based on common sense and own experience about the site conditions. Despite the undoubted knowledge of the site conditions, predictions based on the past and current situation of the site can be significantly biased since may not take into account unexpected feedback present in the system (e.g., the effect of increasing temperature on water abstraction and on the most suitable crops to be produced in a region). A scientific support to generate possible scenarios and to compare their effects on water quality and quantity is certainly a useful tool to enhance the discussion between stakeholders and decision makers.

An open source numerical model based on MODFLOW-OWHM (Hanson et al., 2014) and implemented in the open source graphical user interface FREEWAT is under development as described in deliverable DT2.2.2. The model is capable of modelling the interaction of the aquifer with the river Isar as well as the dynamic of the water table at the monthly scale. The model was used also to predict future water levels under climate change scenarios. The model is currently under development in order to implement the effect of land use change on the water table. Finally, the model could be used to model nitrate dynamics if the module MT3DMS would be activated. The model is user friendly and the graphical user interface (Fig. 3) allows for an easy modification of the scenarios according to the necessity and the proposed site-specific solutions.

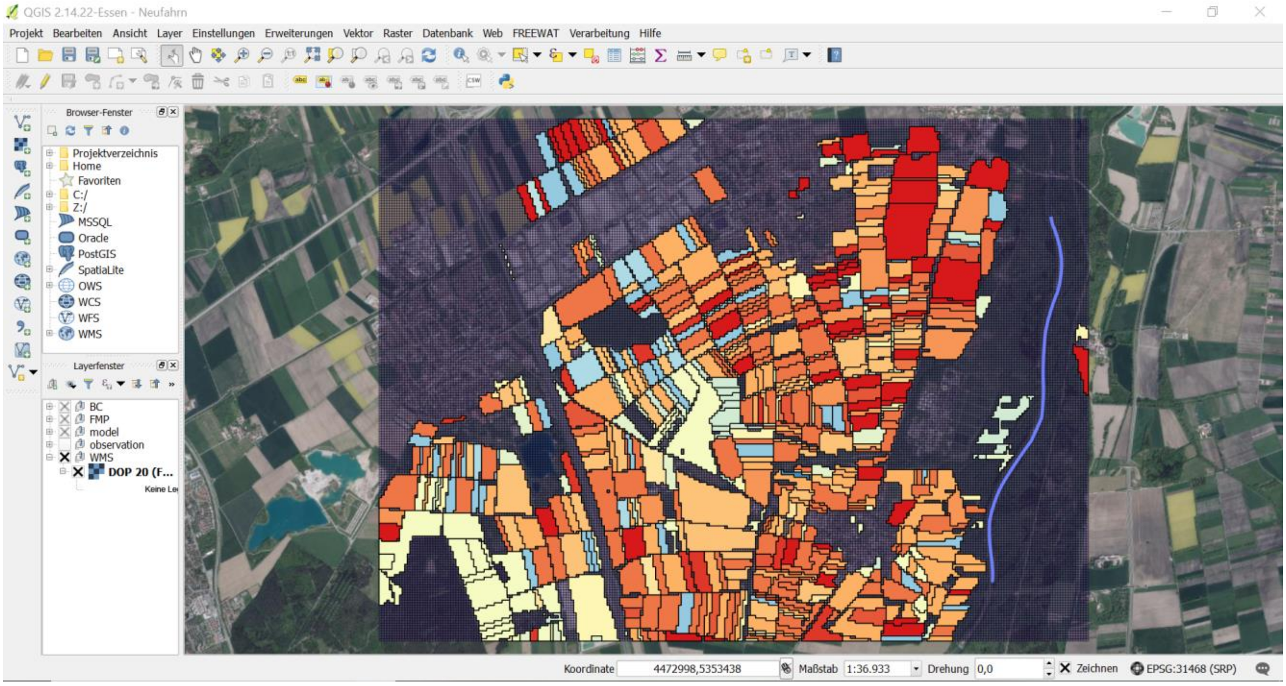

Figure 3: One image generated in the FREEWAT framework representing land use in the Neufahrn bei Freising pilot action.

The output figures are also easy to be interpreted and can guide the decision makers and the stakeholders in the discussion. Despite an expert knowledge is needed to implement the proposed best management practice, once the model is properly set up can be easily used and modified also by non-expert users. The maintenance of the model is not time consuming nor costly and the interested users can be trained using already available on line courses (www.freewat.eu).

2.2. Acceptance of BMPs among stakeholders

2.2.1. Acceptance of the continuous monitoring program

The installation of the continuous monitoring program proposed as best management practice to the water supply association Freising-Süd was warmly welcomed. The main concern was the implementation cost of the measure, since additional monitoring represent a cost which has to be justified beyond the monitoring activities required by law. The problem was solved though the partnership between the Chair of Hydrology and River Basin Management of the Technical University of Munich and the water supply association Freising-Süd.

The University partner has scientific interests in a high-resolution monitoring of the temporal dynamics of major water quality parameters to enhance process understanding and moreover it is interested in offering the students of engineering the possibility of working for their Bachelor and Master thesis on applied problems. Therefore, the University was able to provide the equipment installed in the well field of Neufahrn bei Freising and to finance the installation of an additional monitoring well close to the river Isar and also a gauging station to monitor streamflow along the river (Figure 4). On the other side, the water supply association Freising-Süd supported the training of students, the preparation of the permits for the installation of the monitoring stations and the networking of the University with the local community and the authorities.

Figure 4: The newly installed gauging station in the Isar river in Neufahrn bei Freising.

The main problem encountered during the implementation of this best management practice was the resistance of some public officers in providing information and processing the formal paper work for the installation of the monitoring network. This problem was also highlighted during the stakeholder workshop meeting: Despite the legislation may be adequate for the implementation of a best management practice, the presence of inadequate personnel in decision-making positions can represent an important bottleneck for its implementation.

2.2.2. Acceptance of the hydrological model to find site specific solutions

As reported in deliverable DT2.2.2, while setting up the hydrological model, we continuously exchanged information with the water supply association Freising-Süd. Moreover, we performed field investigation to verify land use and collected historical data about land use and agricultural activities in general. The water supply association Freising-Süd is very interested in the model development but will require tailored training to be able to interpret the results and modify the model according to possible scenarios they may be interested investigating. An important model application will be the implementation of a fourth shallow well to meet the increasing future demand of water extracted from the shallow aquifer. Moreover, we discussed with local farmers and general inhabitants during public events about past and ongoing changes in land management operations, changing structures on farms and pressures from continuous urbanization. As detailed above, after the model completion we will test how user friendly it is and we will distribute it to interested stakeholders. This test will be extremely helpful to test the acceptance of the hydrological model results, since they may be sometimes counterintuitive or show that commonly accepted believes are not actually supported by the data collected in the pilot action.

For the acceptance of model results an important issue has to be addressed, which is the correct communication of the concept of model uncertainty. Model results are indeed affected by different sources of uncertainty (e.g., epistemic uncertainty, related to model structure and the way how physical processes are represented; parameter uncertainty, related to the fact that not all parameters required by the model can be measured with perfect spatial and temporal resolution; measurement uncertainty, related to the fact that measurements used to calibrate the model are affected by errors). It is of pivotal importance to quantify this uncertainty, in order to provide information about the reliability of model results and their accuracy. Moreover, the correct communication of this issue can enhance the transfer of data between stakeholders, since all of them are informed about the importance of reducing model uncertainty and can recognize the advantage of a reliable model to test future land and water management strategies.

2.3. Overview table about implementation of BMPs in Pilot Action and their acceptance among stakeholders

Table 1: GAPs and proposed BMPs with recommendations for implementation in Pilot Action.

<table>
<tr><td colspan="2">Actual management practice (GAP)</td><td>Continuous conversion of (permanent) grasslands</td><td>Public engagement in development of action plans</td></tr>
<tr><td colspan="2">Proposed BMP</td><td>Continuous monitoring program in both, surface water and groundwater</td><td>Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach</td></tr>
<tr><td>Proposed solutions and recommendations</td><td>adaptation of existing land use management</td><td>No adaptation of existing land use management practices required.</td><td>No adaptation of existing land use management practices required.</td></tr>
</table>

	practices		
	Adaptation of existing flood/drought management practices	Invest in infrastructure to increase the monitoring network in the pilot action. Installation of gauging stations on the Isar river, identification of piezometers usable to monitor groundwater level, installation of multi parametric probe that measures continuously relevant hydrogeochemical parameters (water level, water temperature, electrical conductivity, pH, Nitrate, dissolved oxygen)	The availability of a hydrological model can provide relevant information for the stakeholders in terms of water quantity and quality and support decision makers in the implementation of existing flood/drought management practices. The use of the proposed BMP has to be intended in a broader framework which can serve as decision support system for managers.
	Adaptation of policy guidelines	The value of monitoring should be more emphasized in the policy guidelines and water suppliers as well as water authorities should receive incentives to better manage available data and to collect more frequently and with a better spatial resolution relevant hydrogeochemical data.	The value of an available hydrological model is not adequately reported in the current guidelines. This tool is of fundamental importance to find efficient site-specific solutions, to test the implementations of solutions proposed by the various relevant stakeholders and to communicate the decision-making process.
IMPLEMENTATION		Yes	Yes
In case of NO:	• possibility of implementation		
	• proposal of procedure for implementation		
	• other (please, specify)		
ACCEPTANCE AMONG STAKEHOLDERS AND EXPERTS			
	• possibility of implementation	The proposed BMP is of relatively simple implementation. The support of an expert view can help the stakeholder in optimizing the monitoring network finding a good configuration in terms of	The proposed BMP is of difficult implementation. The support of an expert is fundamental for the stakeholder in setting up the model, running it and interpreting the results.

		cost/benefit ratio.	
	• proposal of procedure for implementation	1. Perform a field survey to verify the accuracy of the available information 2. Analysis of the institutional path to ask for the permission of the installation of additional monitoring point 3. Design a monitoring network according to the necessity of the study site 4. Find an optimal cost/benefit configuration of the monitoring network 5. Collect the permission to install new monitoring points 6. Share the data, maintain the database and proof the quality of collected data	1. Perform a field survey to verify the accuracy of the available information 2. Analyse the quality of available data 3. Develop a conceptual model 4. Develop a mathematical model 5. Calibrate and validate the model 6. Use the model to test scenarios proposed by stakeholders 7. Support decision makers providing the model results in a comprehensible form
	• other (please, specify)	Bottlenecks that we identified in the implementation of the procedure are: - complex organizational structure to obtain the permit for the installation of new monitoring points - resistance of some individuals in processing the requests for the installation of new monitoring points - lack of knowledge about the current situation (e.g., it was not possible to identify the owner of some existing monitoring points)	Bottlenecks that we identified in the implementation of the procedure are: - correct communication of the concept of model uncertainty - correct communication of model results which may not be expected by the stakeholders

3. Conclusions

For the pilot area of Neufahrn bei Freising we identified two main gaps: understanding the effects of land use change that can explain the reduction in nitrate concentrations and increase the public engagement in the development of action plans. Two best management practices have been therefore developed to improve the situation. The first one is the installation of an improved monitoring network to better understand the system behaviour and therefor unravel the changes that lead to nitrate reduction. The second one is the development of a numerical model with the purpose of testing and communicating the possible effects of management scenarios proposed by multiple stakeholders. The direct involvement of stakeholders in the development of both best management practices was fundamental for their implementation and the acceptance of the results will be tested also during the next stakeholder meeting.

4. References

- Hanson, R. T., Boyce, S. E., Schmid, W., Hughes, J. D., Mehl, S. W., Leake, S. A., Maddock III, T., & Niswonger, R. G. (2014). One-water hydrologic flow model (MODFLOW-OWHM) (No. 6-A51). US Geological Survey.