ANNEX 7

Neufahrn bei Freising (PA2.5)

SET-UP OF PILOT-SPECIFIC MANAGEMENT PRACTICES

D.T2.1.2 Transnational case review of best management practices in pilot actions

BEST MANAGEMENT PRACTICES REPORT IN PILOT ACTION

"NEUFAHRN BEI FREISING"

FINAL VERSION

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1. Introduction

In this report best management practices are presented on the level of Pilot Action Neufahrn bei Freising, regarding potential conflicts of interest between land use management and water protection.

The aim of this report is to provide the review of best practices regarding different types of land use (agriculture, grassland, forestry) respectively vegetation cover (wetland), aiming at water protection and mitigating floods in the Pilot Action.

For this, first of all human activities have to be identified, which are posing risk to water quality and quantity; flooding and consecutive to water management. Finally, review of best management practices in the Pilot Action is presented.

2. Land use, drinking water and flood protection in the Pilot Action

2.1. Land use

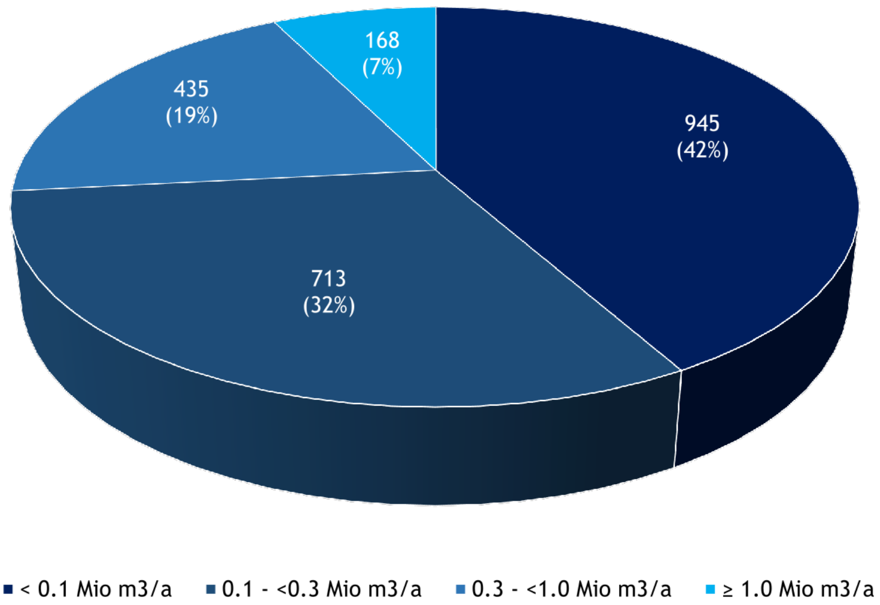

Figure 1: Size classification of Bavarian water suppliers according to their total annual supply of water, modified after LfU (2017a).

The pilot area Neufahrn bei Freising is located about 20 km to the north of Munich (Bavaria, Germany) and covers an area of about 48.8 km2 (4880 ha). The size of the area is characteristic for the Bavarian region, where a large number of small (i.e., smaller than 100 km2) drinking water supply systems are distributed throughout the country (see Figure 1 and Figure 2). The scale of the analysed pilot area is interesting for two reasons. The former is that changes in land use or water management over a small area may rapidly affect water quality and quantity of drinking water. The latter is that the stakeholder workshop and interviews have highlighted how socio-economic dynamics occurring in such a small community (i.e., less than 100.000 inhabitants) are particularly complex. In fact, decision makers are not influenced only by technical arguments but also personal relations among stakeholders play a fundamental role. These two aspects are important for the implementation of best management practices in the pilot area and make it a valuable case study for the project.

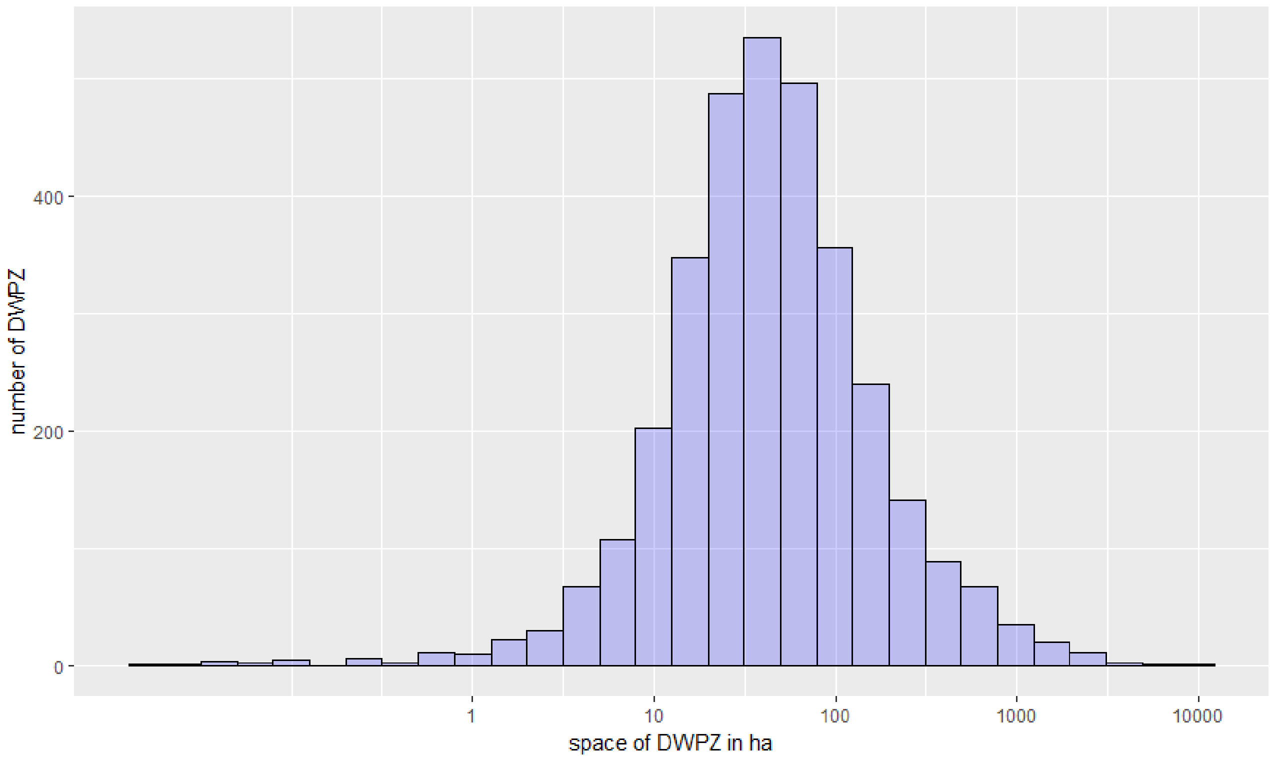

Figure 2: Size distribution of Bavarian Water Protection Zones (DWPZ). (LfU, 2017b)

Based on the GIS analysis performed with the CORINE land cover data from 2012 (BKG, 2012) and validated through orthophotos and site visits, the following land use activities in the pilot area are distributed as follows:

Table 1: Surface cover in the pilot area Neufahrn bei Freising, classified with the CORINE Land Cover dataset from 2012 (CLC 2012), provided by BKG (2016).

CLC code	LABEL 3	Surface area (%)	Surface area (ha)
112	Discontinuous urban fabric	8.57	418.19
121	Industrial or commercial units	11.99	585.00
122	Road and rail networks and associated land	0.02	0.96
142	Sport and leisure facilities	1.22	59.68
211	Non-irrigated arable land	44.86	2189.45
231	Pastures	13.05	637.14
311	Broad-leaved forest	13.76	671.76

312	Coniferous forest	2.10	102.42
313	Mixed forest	1.80	88.08
321	Natural grasslands	1.59	77.53
324	Transitional woodland-shrub	1.03	50.49

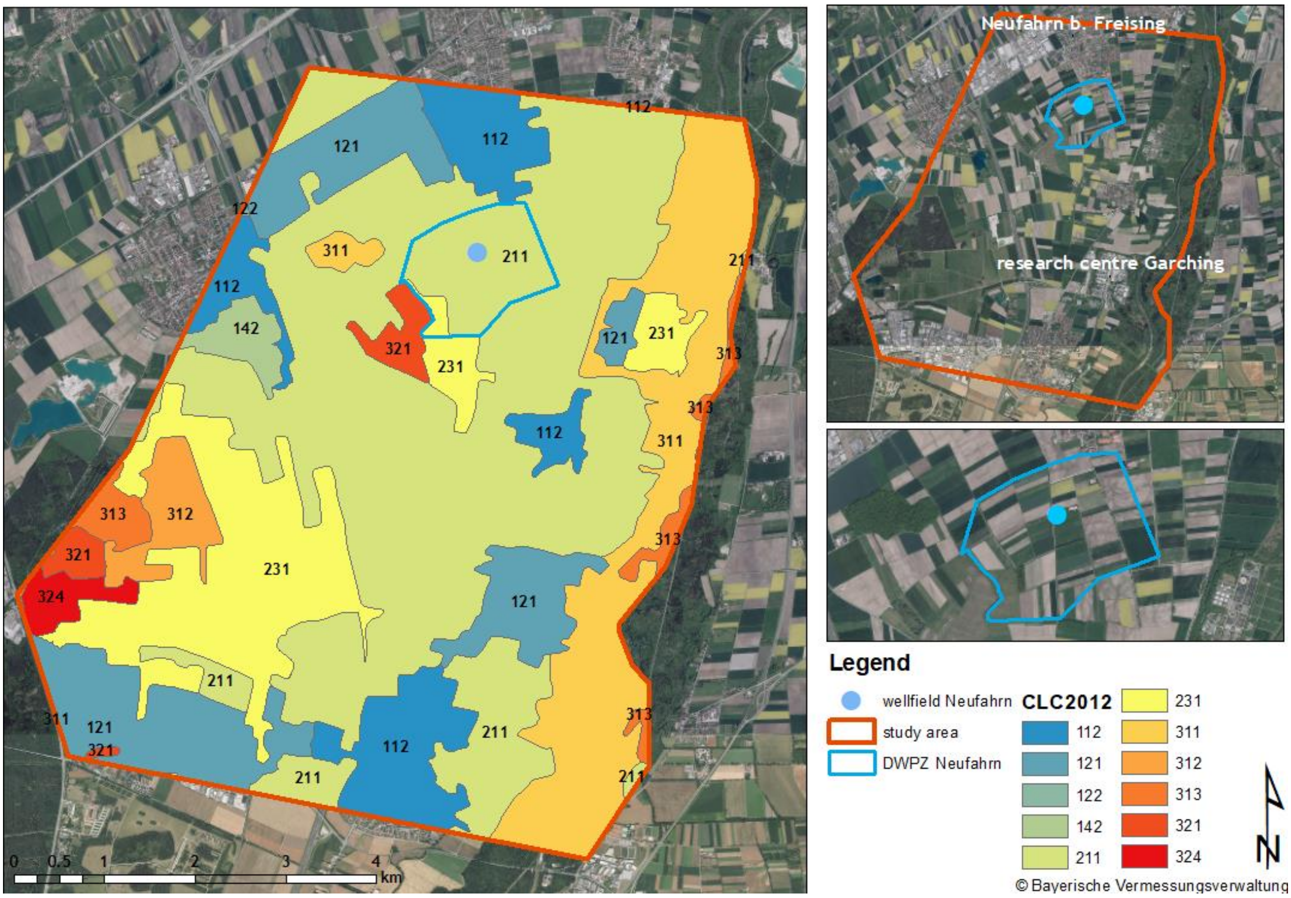

Figure 3: Land use in the Neufahrn pilot area based on CLC 2012, provided by BKG (2016).

As shown in Table 1 and Figure 3, the land use in the pilot area is dominated by (non-irrigated) arable land (44.86 %). As shown in the orthophoto in Figure 3, the size of the cultivated fields is small if compared with the typical size of cultivated fields in other areas of Bavaria and Germany (Bauernverband.de, 2012). The socio-economic reasons for such conditions are currently under investigation. It is important to mention that even though those areas are defined as non-irrigated arable lands in the CLC 2012 classification, we know that irrigation systems are used widespreadly in the pilot area during dry periods (e.g., summer 2017). The main irrigation system is based on sprinklers.

Based on the local statistics for 2010 (LfStat, 2016), about 60 % of the arable land, is used for grain farming. The most frequent grain types are wheat, winter and spring barley. Further important crops are winter oilseed rape (ca. 15 % of the total arable land), maize (ca. 13 % of the total arable land) and potatoes (ca. 3.6 % of the total arable land).

It is particularly important to embed the role of potato farming in the context of land use changes in the regarded pilot area. The statistics provided by LfStat (2016) show that potato farming has halved from 1999 to 2010. As noted by several stakeholders, potato farming was the dominant land use during the last decades of the 20th century since the purchase of the gains was ensured by an international potato product production company (Pfanni) in Munich. However, the decrease of potato farming has two reasons; on the one hand, the operations of the mentioned company stopped in the 1990's, causing the cessation of a secured purchase. On the other hand, potato farming requires more manpower as compared to other, profitable crops. Since the younger generation is neither willing to help on the fields, nor to take over the family business in the adult age, potato farming has lost its profitability.

As indicated by different stakeholders in the interviews carried on during the project, a further considerable change occurred in the early 1990's. They indicated a rush reduction of livestock of about 30% in the study area. The cause behind this rapid change can be related to two main reasons. First, a decrease to unprofitable milk prices: in 2016 dairy farmers were earning less than 30 cents per litre and in some cases as little as 18 cents a litre. That is a drastic loss in earning in comparison with 2013, when they earned as much as 42 cents on each litre. Farmers say they need to earn at least 40 cents a litre to make ends meet (Munchies.vice.com, 2016; Spiegel.de, 2016; Thelocal.de, 2016). Second, a change in the social structures occurred: The younger generation is moving from agricultural and livestock business towards more profitable activities and is not willing to take over the farms of their families. As a consequence, the viability of grasslands for fodder production decreased in parallel, so that a decrease of 30% can be assumed for grasslands as well.

Settlement structures (CORINE codes 112 and 121) take over 20.56 % of the pilot area. These include discontinuous urban fabrics as well as industrial and commercial units. With a considerably lower areal extent as compared to the arable land, forested areas and pastures take over 17.66 % and 13.05 % of the pilot area, respectively. Also this kind of land use has faced important changes in the last decades. The economic crisis and business relocation lead to the closure of some of the largest industries in the area (e.g., Avon cosmetics and the Müller-Brot bread production company closed in 2011) while new industrial and commercial sites have been built close by. (Neufahrn.de, 2017)

In order to provide useful information for this deliverable, we will focus on possible land use pressures on the water quality and water quantity of the shallow wells, further assuming that these risks may impose a danger for the deep wells after some time. Moreover, a continuous monitoring of the of groundwater quality and quantity of the shallow aquifer system is performed since it is exploited for cooling purposes in industrial activities as well as for the research nuclear reactor in the close by city of Garching.

Pressures

Urban areas

drinking water quantity

- increasing land use pressure as evidenced by increasing settlement spaces causes an increase in sealed surfaces, reducing the groundwater recharge area;
- generally increasing land use pressure resulting from land use conflicts, e.g. construction of a further runway at the international airport of Munich might cause a further need for more infrastructure, like roads, accommodations, utility services etc.;

drinking water quality

- increasing land use pressure as evidenced by increasing settlement spaces causes increasing sources of point pollution (e.g. leaky sewage systems);
- generally increasing land use pressure resulting from land use conflicts (e.g. construction of a further runway at the international airport of Munich might cause a further need for more infrastructure, like roads, accommodations, utility services etc.) causing more possible sources of point pollution;
- damaged private sewers can cause a deterioration of the groundwater quality through leakage of wastewater contaminants;
- old industrial locations and sector-specific residuals of possible contaminants pose a risk for the drinking water quality;

Agriculture

drinking water quantity

- conventional soil tillage can cause a compaction of the soil layer (plow layer) and thus hinders groundwater recharge and causes ponding after heavy rainfall events;

- open croplands between the main crops amplifies the threat of surface sealing and decreased infiltration capacity through aggregate destabilization as a consequence of splash effects during rainfall events;

drinking water quality

- improper application of organic and synthetic fertilizers (wrong timing, inadequate quantity) can cause a substantial leaching of nutrients to the groundwater and surface waters;
- overuse of irrigation systems during dry periods in the summer times can cause enhanced leaching of nutrients;
- leaky liquid manure pits can act as sources of point pollution;
- conventional soil tillage generally can cause increased leaching of nutrients (e.g. nitrate) through enhanced mineralization and destruction of the soil structure;
- open croplands between main crops can cause increased leaching of nutrients through enhanced mineralization processes;
- further intensification of farming activities increases the threat of overstressing the soils (e.g. excessive use of heavy machinery and fertilizers);

Figure 4 shows the inundation areas for two different flood events; HQ100 and HQextreme, for which a flood event of 1.5 * HQ100 was used as the assessment basis. The administrative district of Freising, where our pilot area is located, announced that the visualized areas for a HQ100 flood event are secured areas, which means that the following measures are prohibited (Kreis-Freising.de, 2017):

- designation of new building areas;
- construction and extension of structural facilities;
- construction of walls transverse to the river flow direction during inundation events;
- application and deposition of water-polluting substances;
- to increase or deepen the ground surface;

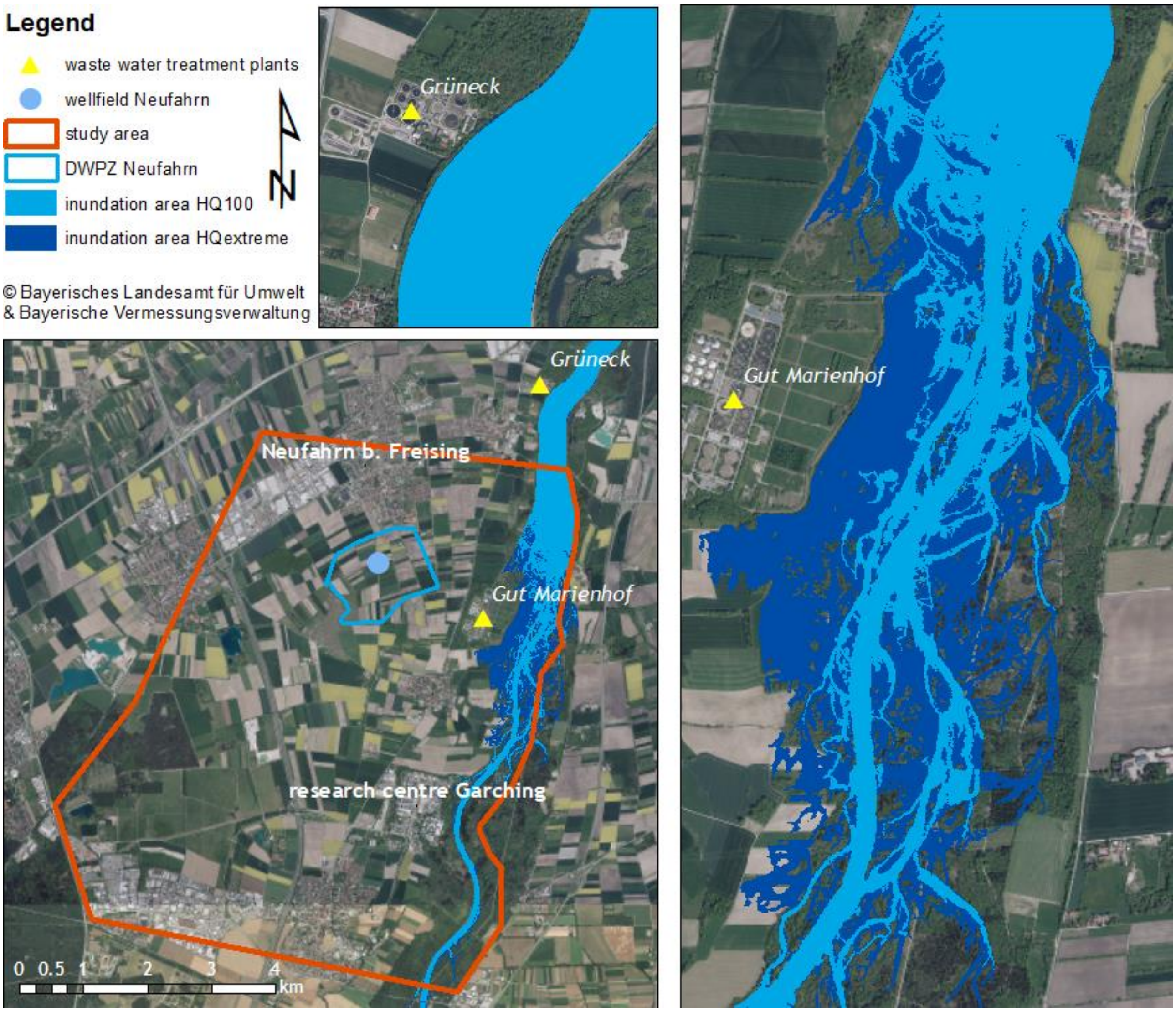

Figure 4: Inundation areas for HQ100 and HQextreme events in the pilot area Neufahrn bei Freising.

Moreover, river floods are also relevant for groundwater management issues in the pilot area. Regarding Figure 5, stream discharge in the river Isar decreases between the gages in Munich and Freising. Moreover, the hydrographs observed at these gages are totally different when focussing on the peak discharges and the summer floods. Those observations can be described by both, the diversion of the river Isar and the Mittlere-Isar-Kanal (see Figure 6) and river exfiltration processes into the connected groundwater aquifers. We assume that the river Isar feds the upper groundwater aquifer in the pilot area, especially during flood conditions, and thus directly controls/affects the water levels in the upper aquifer. Due to high hydraulic conductivities in the Quarternary aquifer (about 1×10-3 to 1×10-4 ms-1), river flood impulses are assumed to propagate quickly through the aquifer resulting in highly dynamic water level fluctuations.

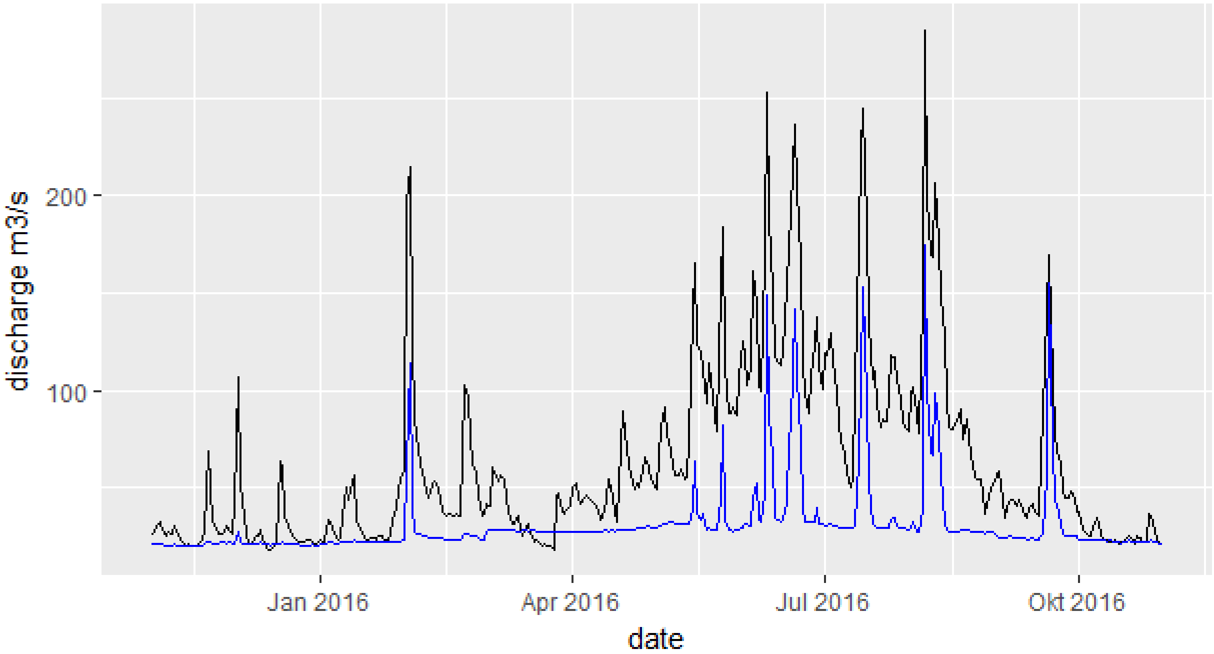

Figure 5: Isar river discharge measured at the gages in Munich (black line) and Freising (blue line) during the hydrological year 2016 (Nov. 2015 – Oct. 2016). (GKD Bayern, 2017)

Such an interaction generally poses a challenge for all kind of constructional requirements. One recent example is the elementary school in Neufahrn. The foundation level of the building was about 0.5 m too low, resulting in a postponement of the school opening as well as in recalculations of the engineering plannings. That surveying error caused a financial loss of more than 400,000 € (Sueddeutsche.de, 2015). Such a shallow and dynamic aquifer system poses also a potential risk for groundwater quality. In fact, flooding of underground storage tanks or storage rooms containing chemicals could open a pathway for contaminant plumes.

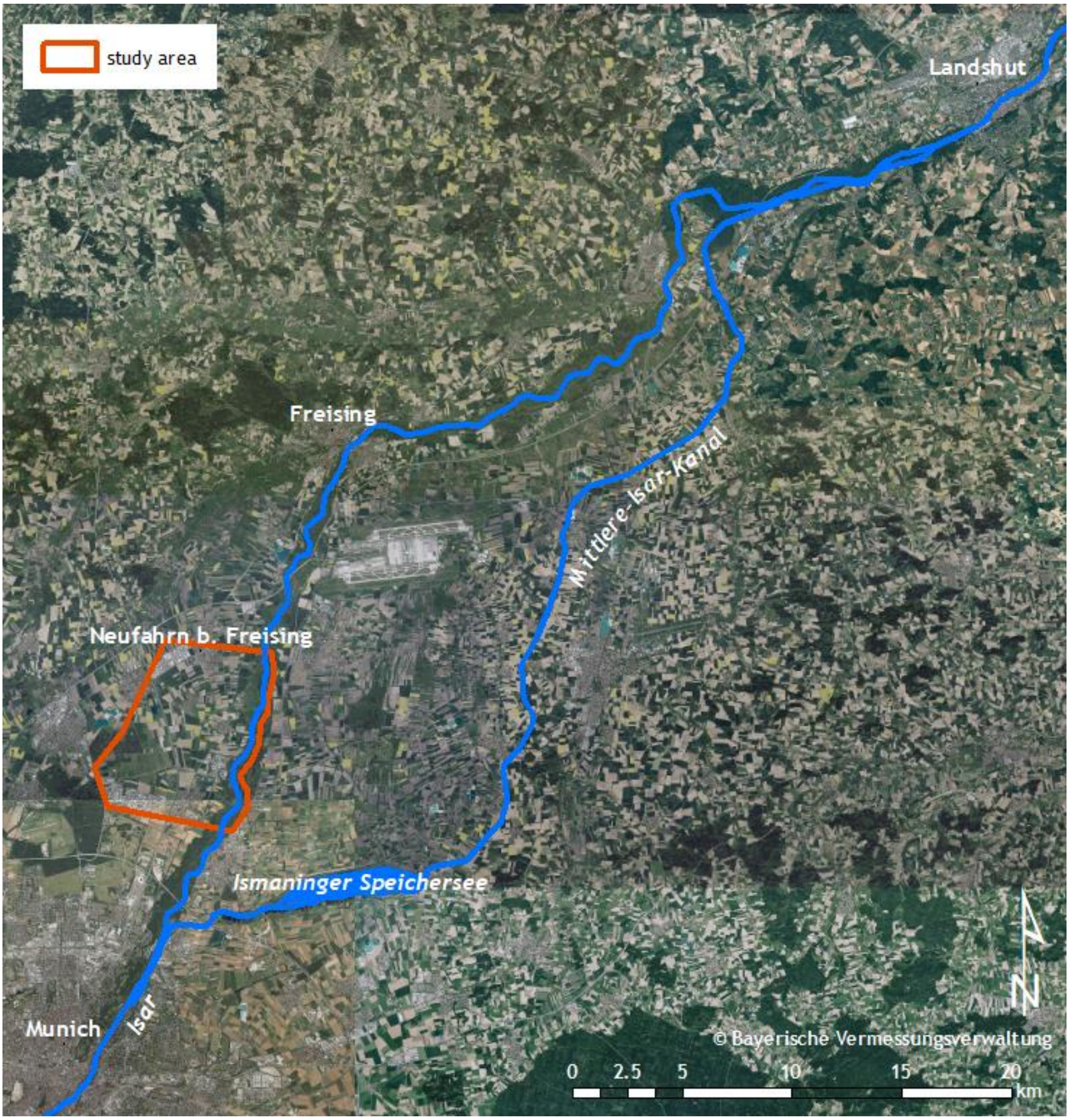

Figure 6: Diversion of the river Isar in the north of the city of Munich.

- interrelations between drinking water and flood management.

As stated in Geotechnisches Büro (1992), river exfiltration is assumed to mostly occur in the north-east of the considered study area during increased river discharge conditions. However, it is further stated that the amount and the duration of river water supplied to the aquifer is too variable to quantify. Due to the dynamic nature of the hydrological system and the high hydraulic conductivities of the Quarternary aquifer, we assume that river water supplied to the aquifer may play a considerable role for the hydraulic behavior of the upper aquifer system in the regarded study area.

Moreover, two quite important waste water treatment plants are located near to the river Isar (see Figure 4) within and closely to the pilot area, respectively. The waste water treatment plant within the boundaries of the pilot area, Gut Marienhof, is one of two plants treating the wastewater of the whole city of Munich. Grüneck, by contrast, is the waste water treatment plant of the water union Freising Süd and is thus directly related to the water management issues in the considered pilot area.

Those plants generally pose a risk for the water quality in case of leaky systems. However, that risk increases during flood events and simultaneously increasing groundwater levels since leakage from those waste water plants could be dispersed more rapidly and extensively, in case of a system failure.

2.2. Drinking water protection

The pilot area Neufahrn bei Freising includes only one drinking water protection zone which is described in the following.

The drinking water protection zone of the water union Freising Süd in Neufahrn bei Freising has been established in 1992 with the primary goal to protect the well field Neufahrn from harmful impacts of anthropogenic activities. The well field comprises 3 shallow wells and 6 deep wells, whereof only the deep wells are used for the local drinking water supply due to the high nitrate concentrations registered in the upper aquifer (see Figure 7). Those deep wells are screened in the hydrostratigraphical units of the Obere Süßwassermolasse (screened at about 30 m to 80 m depth, lower aquifer). The shallow wells, by contrast, are used to provide process water to the Garching research centre and as cooling water for industrial operations. Those wells are screened in the Quarternary deposits (upper aquifer).

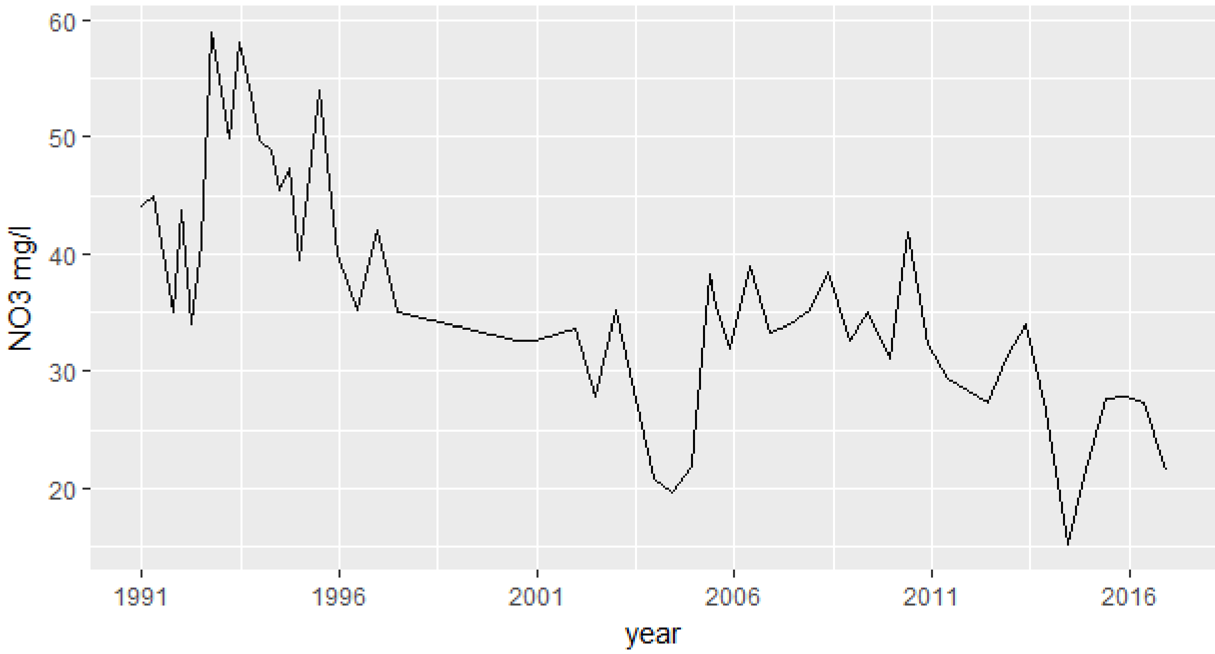

Figure 7: Trend of the nitrate concentrations measured in the shallow well 1 of the well field in Neufahrn.

In order to assess possible risks from land use activities as well as to determine Best Management Practices for the regarded study area, a fundamental understanding about the hydraulic connectivity of both considered hydrostratigraphical units is of primary importance.

Given the assumption that both aquifers are interconnected as well as that evidence for exchange processes on relevant scales is given, a detailed analysis of water quantity and water quality trends as observed in the shallow wells along with hydrological modeling is useful to assess possible threats for the deep wells.

Both, the understanding of the hydraulic interdependencies of the two considered aquifers as well as the modelling of the hydrological processes and trend analysis of relevant parameters (e.g. water level fluctuations, trends in nitrate concentrations) measured in the shallow wells are a matter of current research.

During the last decades (late 1980's until 2016), a continuous decrease in nitrate concentrations measured in the shallow wells could be observed. The decrease of nitrate concentrations can be considered as positive regarding the quality of the Quarternary groundwater. In order to explain such decreasing trend, we have hypothesized three possible causes. The first one, is related to land use management. Since mostly agricultural activities are considered to be the major source of diffuse nitrate contaminations (primarily regarded as non-point sources), the observed decrease in nitrate concentrations may be dedicated to successful agricultural management practices. However, to which particular land use change that decreasing trend may be attributed, which land use activities jointly improved the quality of the water extracted from the shallow wells or to which extent changing hydrological processes may explain the observed trends is a matter of current research. In the pilot area, the shallow aquifer is strongly affected by the interaction with the Isar river, on the Eastern boundary. Another possible explanation for the observed trends in nitrate concentration may be found in the hydrological processes, e.g. dilution processes through river water infiltration and/or increased groundwater recharge through percolation. Finally, the reduction in livestock could have also contributed in decreasing the nitrate input in the shallow aquifer.

Those open questions have been the reason for choosing Neufahrn bei Freising as a pilot area for PROLINE-CE and need to be answered in order to determine Best Management Practices.

2.3. Other protection areas

No further protection zones are located within the considered pilot area.

3. Best Management Practices

It is important to note that gathering data about (agricultural) land use changes is a challenging task since such information for the last decades of the 20th century is principally provided by stakeholders.

Based on the stakeholder interviews conducted so far as well as based on our reviews for D.T1.1.1 and D.T1.2.1, we assume the following management practices to be considerable as Best Management Practices.

3.1. Grassland

Due to the general decrease of livestock in the pilot area (Figure 8), we assume that grazing activities decreased in parallel. So, the existing grasslands are mostly harvested with the respective machinery.

Generally, grasslands are less tilled with heavy machinery as compared to arable lands which avoids an intensive degradation of the site conditions. Grassland soils mostly have a more loosened soil structure which improves the infiltration capacity. Those processes can be further enhanced through the root zone of the turf.

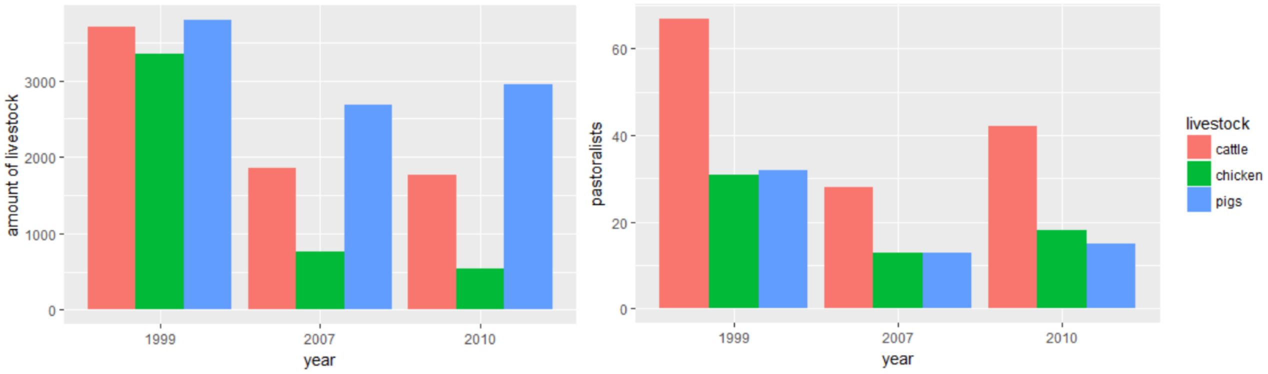

Figure 8: Changes in livestock and pastoralists in the Neufahrn bei Freising pilot area. (LfStat, 2016)

The enriched content of soil organic matter of the topsoil of grasslands favors the water storage capacity and the process of water purification. Bioturbation further positively affects the soil (aggregate) structure; it improves the connectivity of macropores and enhances the infiltration capacity (SCHEFFER et al., 2010). Additionally, the intensity of bioturbation positively correlates with the distribution of macropores which in turn is crucially important for the water provision and water regulation function of the soil system.

A dense turf on grasslands provides a protection function against erosion processes, soil aggregate destabilization and evaporation losses. The turf decreases the susceptibility to surface sealing and lowers the probability of breaching the infiltration capacity and the resulting Hortonian Overland Flow and ponding, respectively. (DWA, 2015).

It is important to note that a plowing up of grasslands can signifcantly increase the leaching of nitrate since on the one hand, huge amounts of organic matter can be decomposed by soil organisms and on the other hand, the natural nutrient uptake by vegetation is interrupted (WHITMORE et al., 1992). The decomposition process is also enhanced by a high solar radiation acting on the unprotected surface. We assume those described interdependencies to be the causing factors for the sudden increase in the nitrate concentrations measured in the shallow wells during the early 1990's (see Figure 7).

Thus, the conservation of grasslands which are not intensively used, neither for livestock farming nor for fodder production, can be considered as a Best Management Practice in the Neufahrn bei Freising pilot area.

3.2. Agriculture

3.2.1. Implementation of catch crop plantations

Exposed and uncovered surfaces represent unprotected areas which are susceptible to negative environmental influences. Splash effects of rainfall can destroy soil aggregates and lower the water storage capacity. More detached, fine-textured soil particles can favor surface sealing processes and lower the infiltration capacity. Moreover, harvest residues on temporally unused lands are likely to foster the mineralisation of nitrogen and lead to increasing amounts of nitrate in the topsoil which can enhance the diffused discharge into the groundwater (SCHEFFER et al., 2010).

In order to lower these negative effects on the water purification and water regulation functions of the soils, the implementation of catch crops plantations is becoming more and more frequent. Basically, catch crops are mostly fast-growing species which overlast the intermediate phase between two main crops and at best remove excess nutrients. Moreover, catch crops are also cultivated simultaneously with species that require a wider row spacing (e.g. maize fields or vineyards) to cover the bare soil between the crop rows. These catch crop species have to be adapted to the main crop since both should not be in nourishment competition for nutrients and at best benefit from each other.

The cultivation of catch crops can significantly decrease the nitrate leaching (e.g. greening in winter). Depending on the species, catch crops can store a certain amount of nitrate which is mineralised after the harvest and thus available for the following main crops (THORUP-CHRISTENSEN et al., 2003; SCHEFFER et al., 2010). Moreover, catch crops cover the bare soil and increase the content of organic matter in the topsoil. Thus, these plantings protect the soil from soil aggregate destabilization and erosion processes. The increased content of organic matter also hinders surface sealing and the related probability to increased surface runoff (MEISINGER et al, 1991; GLAB et al., 2008). Catch crops also increase interception and transpirtation losses and may thus counteract the ecosystem service water provision.

In the Landkreis Freising, farmers become more and more aware of the advantages of catch crop cultivations, also regarding their increasing profitability. (Boden-staendig.de, 2016)

3.2.2. Non-turning soil tillage

Traditional tillage, or more precisely conventional tillage is usually based on soil-turning methods, such as plowing. Thereby the topsoil is loosened and turned so that the organic residues are extensively and equally distributed folded in the topsoil. Primarily, this measure is used to prepare the agricultural land for the following sowing. The plowing also provides a mechanical weed control and enhances the aeration of the topsoil (SCHEFFER et al., 2010). However, this technique can adversely affect the ecosystem services water provision, water regulation and water quality regulation.

This technique destroys the aggregate structure of the topsoil due to the mechanical impact of the plow. The increased aeration in the topsoil fosters the decomposition (mineralisation) process of the organic matter and thus reduces the humus content (SCHEFFER et al., 2010). Both, the destroyed aggregate structure as well as the reduction of the humus content reduce the water storage capacity as well as the purification and filtering function of the topsoil. For example, KANWAR (1985) described higher nitrate leaching from conventional tillage sites than from no-till sites.

A transition from conventional soil tillage to non-turning alternatives (conservation tillage) counteracts these negative impacts of soil-turning methods. Conservation tillage fosters the preservation of the soil structure and its pore system so that the soil maintains its water transferability and storage capacity. Especially the preservation of the vertical pores is of vital importance for water infiltration at the soil surface (SHIPITALO et al., 2000). Moreover, the humus content of the topsoil increases compared to conventional tillage favoring the water storage capacity and the process of water purification. Since the topsoil is not turned in conservation tillage the acitivity of soil organisms does not decrease and keeps the bioturbation on an adequate level (BAUCHHENß, 2005). Bioturbation positively affects the soil (aggregate) structure; it improves the connectivity of macropores and enhances the infiltration (SCHEFFER et al., 2010). Additionally, the intensity of bioturbation positively correlates with the distribution of macropores which in turn is crucially important for the water provision and water regulation function of the soil system.

This method has been proposed in the hydrogeological baseline studies for the delimitation of the drinking water protection zone (Geotechnisches Büro, 1992). We assume that the application of non-turning soil tillage increased during the last decades.

3.3. Urban and industrial areas

3.3.1. Decentralized rainwater infilration systems

Modern engineering plannings basically include recommendations how to implement decentralized rainwater infiltration systems to ensure an extensive surface infiltration as well as water retention.

In this context, different measures are suggested depending of the type of the structural planning. One example is represented by the closed industrial area of AVON cosmetics. For a renovation and a new use of the area and its buildings as an industrial or commercial area, the following measures have been recommended by the engaged planning office (Dragomir Stadtplanung, 2016):

due to the existence of flat roofs, those roofs should be equipped with extensive roof greenings to support the water retention;

as far as possible, rainwater should be seeped extensively, therefore implementing water permeable surfaces for pathways, access roads and other open spaces in order to reduce the degree of sealing;

rainwater seepage from sealed surfaces should further be seeped through extensive infiltration ditches;

Those described measures can be considered as state-of-the art Best Management Practices to improve the water retention as well as the extensive seepage of rainwater in sealed urban and industrial areas.

4. Conclusions

The pilot area of Neufahrn bei Freising is representative for Bavaria due to its size and the land use. The aquifer system consists of an upper and a lower aquifer. The lower aquifer does not present important critical aspects at the moment, while the upper aquifer should be carefully managed due to the following pressures:

Agricultural activities: they represent the main pressure due to nitrate inputs. A decreasing trend in nitrate concentration is observed, but the reason for such positive outcome is unclear and should be carefully investigated with the purpose of applying the same management practice in other regions.

River water-groundwater interaction: the river Isar, located along the eastern boundary of the area exchange a relevant amount of water with the aquifer representing therefore a potential contamination source. Moreover, the complex interaction between surface water and groundwater considerably increase the uncertainty related to the groundwater flow direction and hence to the definition of an appropriate groundwater protection zone.

Waste water treatment: the waste water treatment plant of Gut Marienhof may represent a threat for the well field in case of system failure.

Both aquifers are a valuable water resource for the area and the lower aquifer, used for the drinking water supply system of Freising Süd water authority, is connected with the upper aquifer. Hence a proper management of the upper aquifer is highly recommended to protect the lower one.

Socio-economic changes are rapidly occurring in the pilot area. In particular, a decrease in interest for agricultural activities may lead to important changes in land use and land management in the next years. Moreover, also the urban area is rapidly changing, with the construction of new commercial and residential areas and a change in the industrial activities. Such a dynamic environment represents a challenge for water management when they need to choose the most appropriate land use management practices.

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