Chapter 9

Mariusz Adynkiewicz-Piragas, Iwona Lejcuś,
Joanna Kryza, Iwona Zdralewicz

Examples of Good Practice in the Management of Groundwater Resources

1. Introduction

Sustainable Hydro Assessment and Groundwater Recharge Project (SHARP; nr 0873R2) is carried out by the Institute of Meteorology and Water Management National Research Institute Branch in Wrocław (IMGW – PIB OWr) and 8 European partners under European Territorial Cooperation Programme INTERREG IVC. Funds for the project comes from the ERDF. The Project aim is to protect the existing water resources with particular emphasis on groundwater. Furthermore, both climate change and geological and geographical conditions are also taken into consideration. The key issues of the SHARP project which need to be solved and implemented are as follows (Adynkiewicz *et al.* 2011):

1. General tools for groundwater management.
2. Artificial groundwater recharge technologies.
3. Groundwater monitoring systems.
4. Strategic use of groundwater for the purposes of industrial use, drinking water and irrigation.
5. Techniques for protection of the quality and quantity of water.
6. Drinking Water Safety Plans along with tools for risk management.
7. Models of water balance.

The IMGW – PIB Wrocław Branch started the implementation of the SHARP project in April 2010. It is scheduled to be finished at the end of 2012. The aim of the work carried out by the IMGW – PIB Wrocław Branch is a project of protection and monitoring of groundwater resources for the needs of stabilization of groundwater table in antropegenically transformed area, project of a decision support system for the needs of groundwater management for the Polish part of the Lusatian Neisse (Nysa Łużycka) river basin. What is more, the project partners improve their knowledge on existing technologies applied by other partners (Austria, Italy, United Kingdom, Germany, Malta, Greece).

The Lusatian Neisse river basin is the research basin incorporated in the activities of the SHARP. It is located in the south-western part of Poland. Its area is 4395 km^2 (Fig. 1). The Lusatian Neisse river is a left-side tributary of the Oder river. Its total length is 246 km. It is a trans-boundary river, which major part of its course comprises the Polish-German border. The greatest disturbances of groundwater resources in the region date back to the mid-twentieth century. Water conditions in the area are influenced by strong anthropopression. The ongoing extraction of opencast lignite at one of the Polish mines (Turów) and three German mines (Jänaschwalde, Reichwalde, Nochten) as well as the reclamation of Berzdorf mine (Fig. 1) have had a significant impact on the aquifers.

Due to the specifics of the present basin, SHARP project presents IMGW OWr experiences connected with long-term monitoring of areas subject to anthropogenic transformation and connected with analysis of interaction between surface and underground waters tables as well as the changing and formation of a quaternary groundwater aquifer table along the Lusatian Neisse river. These are examples of good practices for the reconstruction of underground water table. A piece of good practice is the method that:

- has been already carried out and is characterized by high efficiency,
- has the characteristics of innovative solutions,
- may be successfully applied in other similar regions.

It should be mentioned that good practices are any periodic or one-off undertakings which allow an effective and efficient completion of tasks and in consequence achievement of its goals. The activities should have a universal nature. In other words, they should be ready to be implemented in other similar cases. It seems obvious that good practices (like for instance groundwater monitoring network in anthropogenically transformed areas) cannot be directly or completely copied and thus transferred over to similar cases; they have to be creatively adjusted to a particular situation. Nevertheless, it is often advisable to indicate and shorten the way leading to the improvement or systemic solution to a problem. The presented good practices are valuable and proven solutions which can be adapted in order to support management processes at local government units. Consequently, it is often the key factor enabling the development of areas where municipalities and administrative districts struggle with problems connected with disturbance of groundwater resources.

2. Materials and methods

The first good practice presented in the project concerns a groundwater monitoring network in the area which has been subject to anthropogenic transformations. The network is a source of information on groundwater in the region (Fig. 1). The monitoring network, which was created for the needs of good practice, is based on several networks used for numerous tasks performed by the IMGW – PIB Wrocław Branch. These are: a special network set up for the needs of trans-boundary cooperation with Germany (German-Polish Commission on Trans-boundary Waters), monitoring network set up for the needs of evaluation of water conditions/ relations in the southern part of the river basin (Quaternary groundwater), telemetric network of hydrologic stations (5^{th} grade) of the National Hydrological and Meteorological Forecast Service (PSHM, Quaternary groundwater), a network of domestic wells set up for the needs of the observation of impact of flooding in the Berzdorf mine on groundwater on Polish side. The database contains results of the measurements of the depth of the water table position as well as the results concerning the atmospheric precipitation totals and thermal characteristics of the area of the Lusatian Neisse river basin. The data comes from the database of PSHM and measurements made by Department of Regional Research IMGW – PIB Wrocław Branch.

Significantly disturbed resources of aquifers in the Lusatian Neisse river basin, lead to the necessity to restore groundwater tables. Results of long-term monitoring carried out in the area of open cast mines which are active or are being re-cultivated in terms of water, allow assessment of changes that take place in those particular aquifers. The interrelation between groundwater and surface water is a complicated phenomenon, which depends on the location of water table in surface water reservoirs (lakes, rivers). Additionally, the relation is influenced by various natural processes comprising of a number of factors:

- the degree of indentation of riverbed in a layer (aquifer),
- drainage base which is a mean value ordinate of the surface water table,
- conductivity of hydraulic contact of aquifer with surface water reservoir,
- thickness and filtering parameters of aquifer,
- contact area of surface water reservoir,
- thickness and filtering parameters of sediments constituting the riverbed.

The second presented good practice concerns the evaluation of interdependence of surface water and groundwater. It is based on analysis of observations series of surface water, groundwater levels and atmospheric precipitation in the area. Evaluation conducted this way on the basis of daily data from IMGW-PIB stations, enables to calculate the correlation between surface water and groundwater. The figure below shows an exemplary relationship at a monitoring point in Posada and at the water-gauge on Sieniawka in comparison to precipitation recorded by the precipitation station on Sieniawka (Fig. 2).

In order to investigate the occurrence and strength of relationships between variables, namely surface water level and groundwater level, a correlation coefficient was calculated for each pair of variables which is information on the strength of the relation. The first step was to establish normal distribution so the Kolmogorov-Smirnov test was used with Lillefors's adaptation for which a null hypothesis was assumed as: H_0. As a result of the analysis, this hypothesis was rejected, which means that the variables do not have a normal distribution. In this case, nonparametric Spearman rank correlation was used, resulting in calculated

Spearman's rank correlation coefficient (r_s). The interdependence of the phenomena is expressed as a linear relationship (Fig. 3).

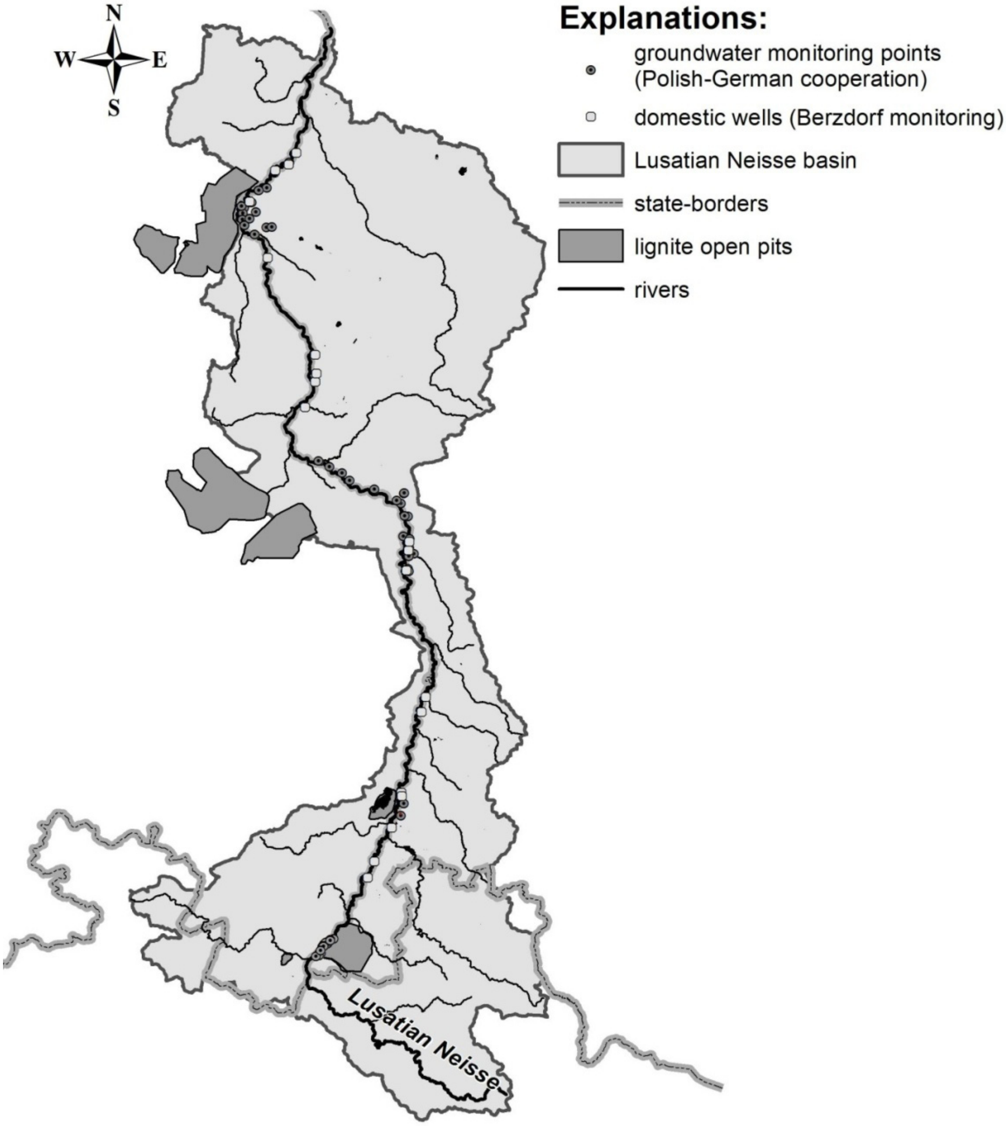

Fig. 1 Location of monitoring points

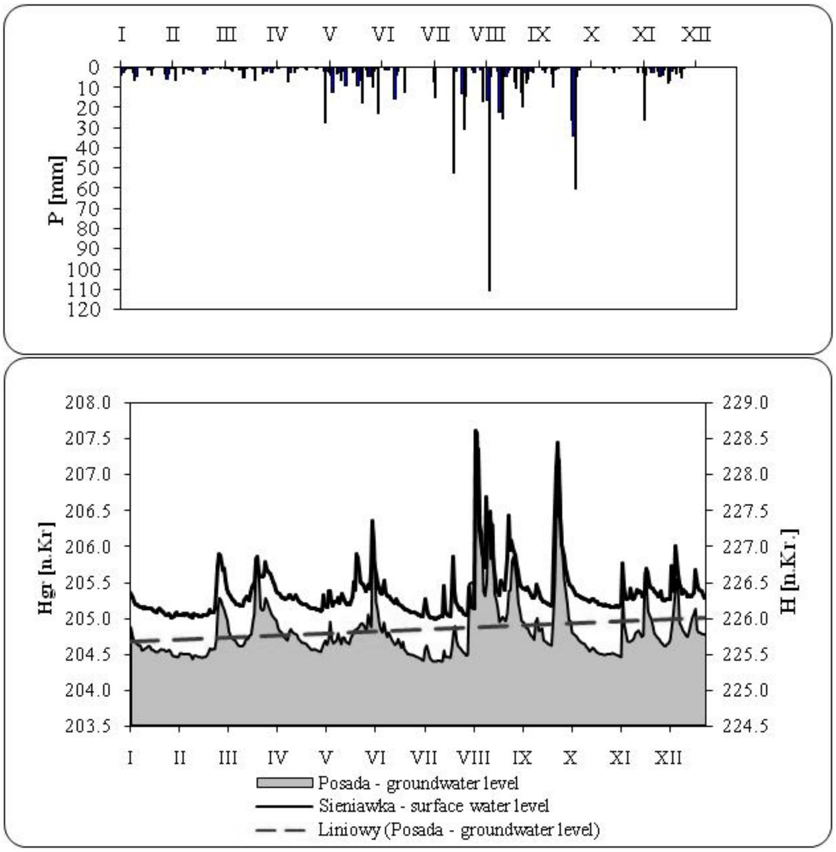

Fig. 2. Sample sequences of observational data: precipitation (top) 2010, surface water the Neisse and groundwater level Posada (bottom)

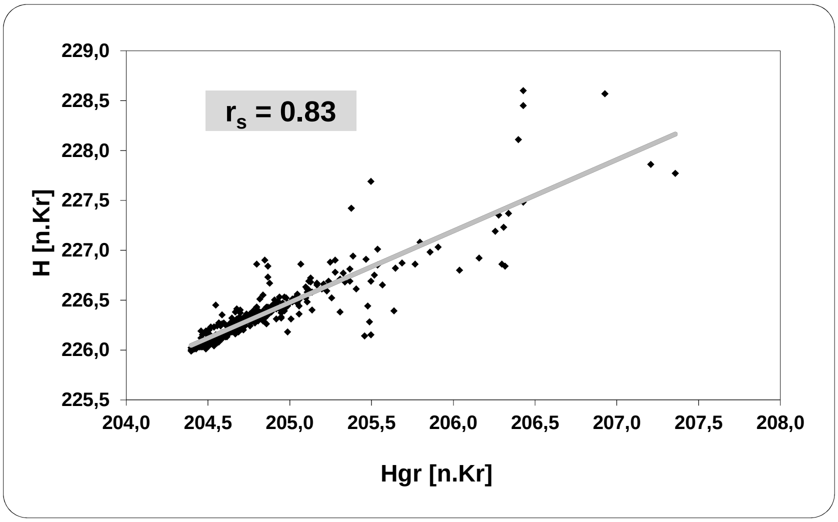

Fig. 3. An example of the relationship of groundwater (Posada) and surface water (Neisse) from selected observation stations in the catchment of Neisse

3. Results and discussion

Many-year's data series allow to determine the changeability and development of the Quaternary aquifer groundwater table along the Lusatian Neisse river. The monitored curve of the water table was typical for transitional climate of Poland. Most often, the highest level of groundwater was noted in the spring thaw season (March) and it remained high till around April. In summer, the water table sunk due to increased evaporation and transpiration as well as constant groundwater drainage. Autumn rainfall and reduced evaporation in this period caused the groundwater level to rise. In winter, especially when it was very cold, the infiltration stopped. Consequently, the groundwater level sunk due to the lack of water supply. The curves of groundwater level in the Lusatian Neisse valley were specified by the different types of curves: mixed, hydrological and linear (Siemichatow 1960). In most of the analysed observation points, the course of the groundwater table is a mixed type curve. In individual cases (Fig. 2) the reaction of the position of groundwater table reflects the changes in surface water table. Only in case of two wells, the linear type of curve with slight fluctuations was observed.

Many-year's observations of groundwater and surface water relationship of the Lusatian Neisse river allowed to determine fluctuations of the phenomena as a result of the influence of atmospheric precipitation. Short-term high water levels on the river are reflected in the groundwater levels with some delay as a result of percolation through the deposits of the substratum or with an even greater delay observed in wells located far away from the river. The short-term high water levels do not affect groundwater in wells located further than 200 m from the river. Reactions in all observation wells were observed during the flood in August 2010 (Fig. 2).

Mean values of Spearman's rank correlation coefficient, in the period 2003-2010, fluctuated from r_s=0,35 to r_s=0,87. The values are presented in Table 1.

The analysis of the relationship between the groundwater and surface water in the Lusatian Neisse river basin for the period 2003-2010 showed that in the upper course of the river the relationship is weak. It can be caused by a greater slope of the river as well as the geological structure. In this area, there are deposits of weak permeable clay, boulder clay, loess. In wells situated near the river (well No. 1, well No. 3), the relationship with surface water is clear which results from lithology (permeable deposits in the watercourse of the river – gravels, sands, alluvial soils). The middle part of the river basin is characterized by the weakest values of correlation coefficient (the character of the relationship is "very weak" or "weak"). It is mainly influenced by the geological structure, namely glacial sediments, which are the remains of Scandinavian glaciations. The sediments are mostly visible in the form of moraines constituting the Muskau Embankement (Wał Mużakowski) (well No. 12, well No. 15). In the lower course of the Lusatian Neisse river a strong correlation between groundwater and surface water is observed. The geological structure in the area (well permeable sands and gravels) contributes to an good contact of groundwater and the river and effective recharge process from the atmospheric precipitation (well No. 23, well No. 22).

Another issue of the analysis connected with the Lusatian Neisse river basin concerns the use of surface waters for stabilization and restoration of groundwater resources. The chosen methodology for determining the dependence of surface water and groundwater was used in the region of an inactive, German Berzdorf lignite mine (to the south of Zgorzelec). In the Berzdorf mine area, which is situated within the fault block depression, the area of depression cone at the end of the process of extraction of coal was estimated at 14 km^2 (Kraftwerke… 1995). After finishing mining activity, the Germany started water reclamation. This type of reclamation activities aims at restoration of natural water conditions, in particular: compensation of quantitative water deficit caused by mining activity by filling the open pit with soil and then flooding it, filling the depression area around the mine with water, recreation of water quality to a level acceptable by the community and creation of the new ecosystem as an attempt to recreate natural environment connected with the newly created lake. Flooding the pit with transboundary water from the Lusatian Neisse river and the Pliessnitz river (Monitoring…2004, Kolba 2005). Reclamation of the structure by flooding the postmining pit and the resulting decrease of the pit water deficiency resulted in the rise of piezometric pressure in deeper aquifers which had been depressurised before. The permeable wall saved waters in overburden sediments in the territory of Poland from dewatering. Thus, the rise of water in the sediments cannot be observed (Monitoring…2011). Consequently, the changes of water level in observation wells of Quaternary aquifer which have been observed since 2003, are the result of seasonal fluctuations and climate-hydrological situation in the river basin only. In the Tertiary-between-coal aquifer which is under the influence of Berzdorf reservoir, the piezometric pressure has risen by 16 meters since December.

To sum up, the methodology for assessing the relationship between surface water and groundwater by the use of regular comparative analysis of observation series of the studied phenomena (status of surface water and groundwater) seems to be considerably simple to apply. Nonetheless, the assessment of the statistical relationship using the Pearson's correlation coefficient requires continuous observation of amplitude of changeability of studied features. The use of systematic correlation of observed series for assessing the impact of surface water intake on groundwater allows for an adequately quick reaction to apply protective means for the nearby farms which use the groundwater from domestic wells. Regular analyses of interdependence of surface water and groundwater level on the basis of existing observation networks are a relatively cheap and quick tool for obtaining a general overview of the studied phenomena in a particular area. The general overview allows for determination of smaller zones characterized by worrying time-spatial variations of the studied features for which additional, often more expensive, tools can be applied for the quantitative assessment of the studied phenomenon. Such an approach, from general to detail, enables to reduce the expenses.

Table 1

Corelation coefficient values

Watergauge	No. of well	Distance from L.N.	Spearman's rank correlation coefficient								Multiyear avarage
		[m]	2003	2004	2005	2006	2007	2008	2009	2010	2003-2010
Sieniawka	1.	30	0.93	0.94	0.92	0.88	0.77	0.72	0.91	0.92	0.87
Sieniawka	2.	200	0.87	0.57	0.73	0.53	0.58				0.66
Sieniawka	3.	100	0.82	0.75	0.82	0.66	0.79	0.59	0.61	0.77	0.73
Zgorzelec	4.	300	0.82	0.64	0.75	0.64	0.68	0.77	0.55		0.69
Zgorzelec	5.	200	0.80	0.42	0.68	0.36					0.57
Zgorzelec	6.	800	0.84	0.65	0.73	0.24	0.25	0.33	0.46	0.83	0.54
Zgorzelec	7.	400	0.78	0.60	0.70	0.49	0.43	0.58	0.48		0.58
Zgorzelec	8.	500	0.81	0.68	0.69	0.50	0.68	0.77	0.43		0.65
Zgorzelec	9.	250	0.84	0.82	0.81	0.74	0.80	0.86	0.55	0.85	0.78
Zgorzelec	10.	350	0.78	0.32	0.23	0.07					0.35
Przewóz	11.	500	0.88	0.80	0.78	0.49	0.59	0.79	0.31	0.74	0.67
Przewóz	12.	600	0.87	0.41	0.75	0.28	0.33	0.61	0.28		0.50
Przewóz	13.	400	0.93	0.69	0.62	0.39	0.70	0.75	0.55	0.77	0.67
Przewóz	14.	250	0.92	0.75	0.21	0.34	0.65				0.58
Przewóz	15.	500	0.92	0.68	0.45	0.40	0.09				0.51
Klein Bad.	16.	800	0.88	0.77	0.83	0.58	0.60	0.84	0.60	0.76	0.73
Klein Bad.	17.	500	0.80	0.35	0.61	0.44	0.41	0.65	0.47		0.53
Klein Bad.	18.	600	0.83	0.51	0.63	0.58	0.14	0.56	0.51		0.54
Klein Bad.	19.	300	0.86	0.72	0.73	0.63	0.64	0.73	0.49	0.67	0.68
Sacro	20.	150	0.88	0.82	0.82	0.85	0.77	0.85	0.67		0.81
Albertin.	21.	150	0.79	0.83	0.84	0.49	0.49	0.65	0.68	0.57	0.67
Albertin.	22.	600	0.91	0.86	0.88	0.83					0.87
Schlagsdorf	23.	200	0.93	0.84	0.93	0.71	0.85	0.90	0.82		0.86
Schlagsdorf	24.	300	0.78	0.67	0.86	0.73	0.57	0.89	0.68		0.74
Schlagsdorf	25.	400	0.82	0.71	0.88	0.79	0.50	0.80	0.82		0.76

Wells: 1. Posada, 2. Bratków, 3. Krzewina, 4. Radomierzyce 31, 5. Radomierzyce 66, 6. Koźlice 8, 7. Koźlice 27, 8. Żarka nad Nysą, 9. Lasów, 10. Pieńsk, 11. Sobolice, 12. Sanice, 13. Dobrzyń, 14. Bucze, 15. Łęknica, 16. Żarki Wielkie, 17. Siedlec, 18. Bukowina, 19. Olszyna, 20. Janiszowice, 21. Późna, 22. Markosice, 23. Sadzarzewice, 24. Polanowice, 25. Sękowice

4. Conclusions

1. The presented good practice of groundwater monitoring in the anthropogenically transformed area is one of elementsc of a complex environmental impact assessment. The demonstrated monitoring network is an example of a solution to the assessment of water resources in similar areas which has been anthropogenically transformed.
2. The developed concept of monitoring can be used in order to create monitoring system not only on anthropogenically transformed areas but also in others with minor modifications taking into account environmental conditions of such an area (hydrogeological conditions, land use, hydrography etc.) and users.
3. Regular analyses of fluctuations in the dependence of the levels of surface and groundwater (assessment of statistical dependence using Spearman’s rank correlation coefficient) based on existing observation network is a relatively cheap and quick tool to achieve a general overview of the studied phenomena in the study area.
4. Additionally, many-year’s observations and analyses can be an alternative source of information in the case of a temporary break in the observation of a phenomena (e.g. in the case of a failure of measurement equipment or end of observation). On the basis of a long measurement series of a given phenomenon and acknowledged beforehand interdependence, it is possible to retrieve the course of the phenomenon in which the measurement series were lost or the monitoring was ended.
5. The assessment of the existing interaction between surface water and groundwater as well as the character of the dependence based on the analyses of observation data series is a crucial control element. What is more, it is a sort of introduction to the issue of water management in a given area. Both observation data series and correlation of its fluctuations may be used for further studies on the problematic area. For instance, determination of the quantitative relationship between a number of phenomena, quantitative assessment may be performed by numerical modelling.

References

Adynkiewicz-Piragas M, Zdralewicz I., Kryza J., Lejcuś I., 2011. Zrównoważone zarządzanie zasobami wodnymi i praktyki odnawiania zasobów wód podziemnych – założenia i wstępne wyniki projektu SHARP. In: Nauka Przyroda Technologie, Szczyrk (in print).

Kolba M., 2005. From old lignite mining pits to New lakes: The example of rehabilitation of the former open-cast mining facilities at Berzdorf, Germany. World of mining. Surface & Underground, 61, 5: 289- 299.

Kraftwerke und Tagebaue beiderseits der Deutsch-Polnischen Grenze, Elektrownie i kopalnie po obu stronach granicy polsko-niemieckiej. 1995. Polsko-Niemiecka

Komisja ds. Współpracy Sąsiedzkiej w Dziedzinie Ochrony Środowiska. Berlin/Warszawa.

Monitoring Nysy Łużyckiej. Część polska. Raport I-XII 2003 r. 2004. Maszynopis. IMGW OWr, Wrocław

Monitoring Nysy Łużyckiej. Część polska. Raport I-XII 2010 r. 2011. Maszynopis. IMGW OWr, Wrocław

Siemichatow A. N., 1960: Hydrogeologia, PWRiL, Warszawa

Mariusz Adynkiewicz-Piragas, Iwona Lejcuś,, Joanna Kryza, Iwona Zdralewicz
Institute of Meteorology and Water Management – National Research Institute,
Department in Wrocław
Regional Research Branch
ul. Parkowa 30, 51-616 Wrocław