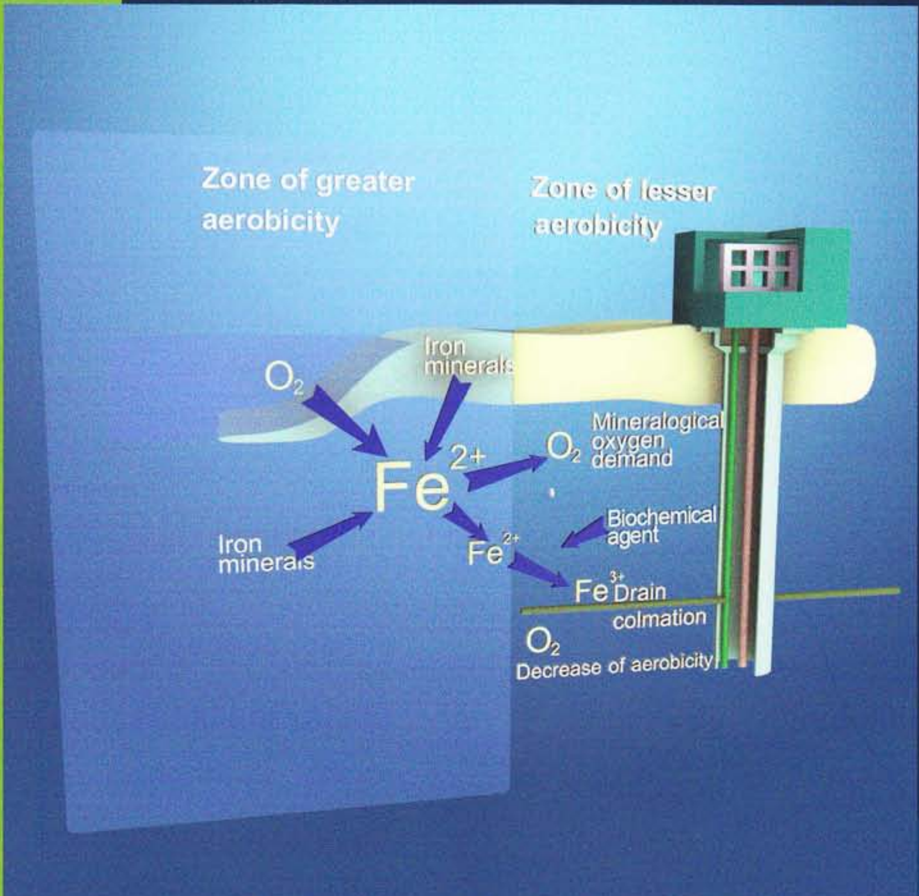
IWA SPECIALIST GROUNDWATER CONFERENCE



International Water Association

Jaroslav Černi Institute for the Development of Water Resources

Belgrade Water Supply and Sewerage Company

PROCEEDINGS

08-10 September 2011, Belgrade, Serbia

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ECOLOGICAL ASPECT OF SUSTAINABLE DEVELOPMENT OF THE MUNICIPALITY OF LAPOVO

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INTRODUCTION

Development of most human settlements in Serbia, in the second half of the 20th century, can generally be described as industrial. This resulted in significant side effects on natural resources, mainly caused by a lack of ecological awareness when industrialization was planned, then carried out. The rise of ecological awareness in Serbia was slightly behind developed countries then. Unfortunately, it was emphasized when transition started, especially due late transition start. The Committee on Human Settlements of the Economic Commission for Europe (ECE) has established a bearing for sustainable human settlements development treating its three main aspects (Lujanen, 1996): ecological, economical and social equally (combined with the role of the so-called third sector, with integration of GIS in the human settlements sector).

ECE recommended that the ecological aspect of sustainable development was to be perceived through five components: fresh water resources, traffic, waste management, energy consumption, and green structure.

This paper illustrates how inconsistent planning and partial problem-solving can lead to a negative impact on the environment. On the other hand, this is an individual attempt to emphasize that proper data base organization is a very important step when urban management is to be performed properly. So, this paper treats all the components in sense of forming an appropriate data base. Combining provided layers is supposed to be a significant platform for sustainable municipal management planning, which is inevitable if remediation is expected/wanted.

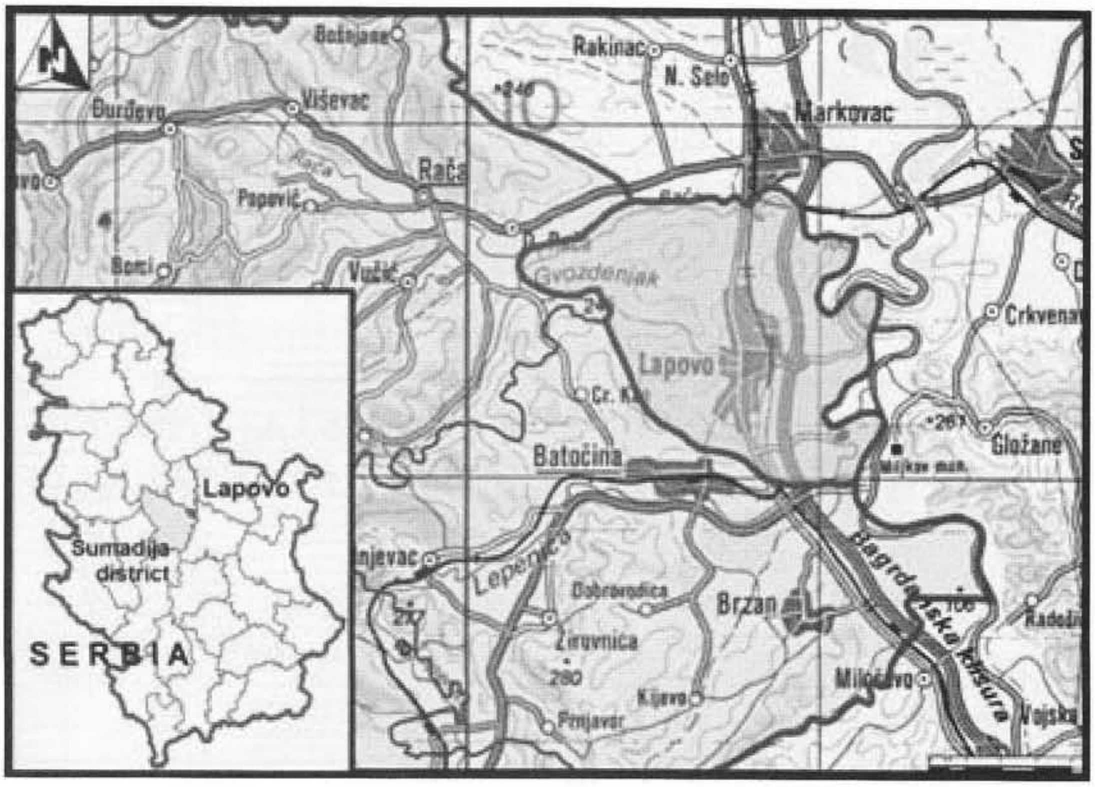

Figure 1: Location Map

RESEARCH AREA

The research area is framed in Lapovo, a municipality situated in the central part of the Republic of Serbia, in the NW part of the Šumadija District. The Velika Morava River is one of the most significant domicile rivers and Lapovo fits in the central part of its basin (Fig. 1).

Lapovo`s good position on international route E75, with a junction of the international Belgrade-Niš-Athens railway line ensures a high potential for further economic development. On the other hand, it exposes it to a threat for pollution threat.

Like all other neighboring municipalities, Lapovo has suffered from major urban management problems. As a result of anthropogenic impacts on natural resources, the standard of living deteriorated during the past two decades. Thus, among other factors, this might be the one closely linked to population decrease.

There is a general trend of population decrease in Serbian municipalities as a result of various factors. Figure 2 shows the specific population increase ($\frac{population\ difference}{time\ step}$) in Šumadija District municipalities by census year. It is apparent that other than Kragujevac and Aranđelovac, all municipalities exhibit a significant decrease, especially in the past decade.

What differentiates Lapovo from neighboring municipalities is a significantly higher mortality rate (Fig. 3), which might be the criteria for linking population decrease with the deterioration of the standard of living as a result of anthropogenic impact on the environment.

METHODS OF EVALUATION

Following ECE`s recommendations for evaluation of the five mentioned components the of ecological aspect of sustainable development, Lapovo should be described as follows:

Fresh water resources issues of the Lapovo Municipality are not supposed to be quantitative, since the water-supply source Garevina is situated in an up to 3 km wide, 5 to 15 m deep, alluvial

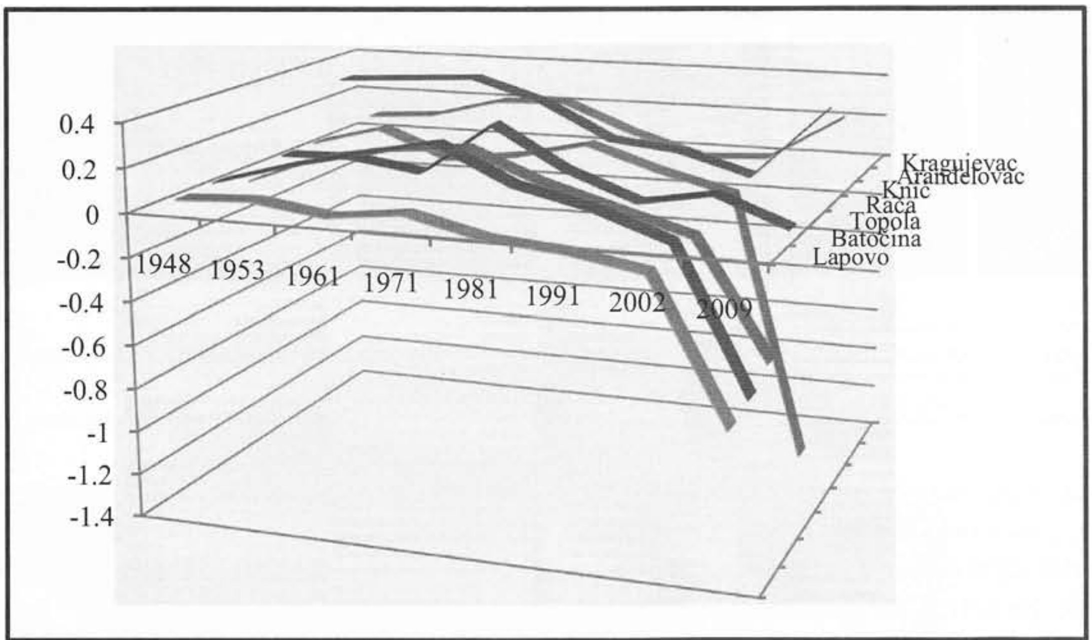

Figure 2: Municipalities of the Šumadija District – Specific Population Increase by Census Year

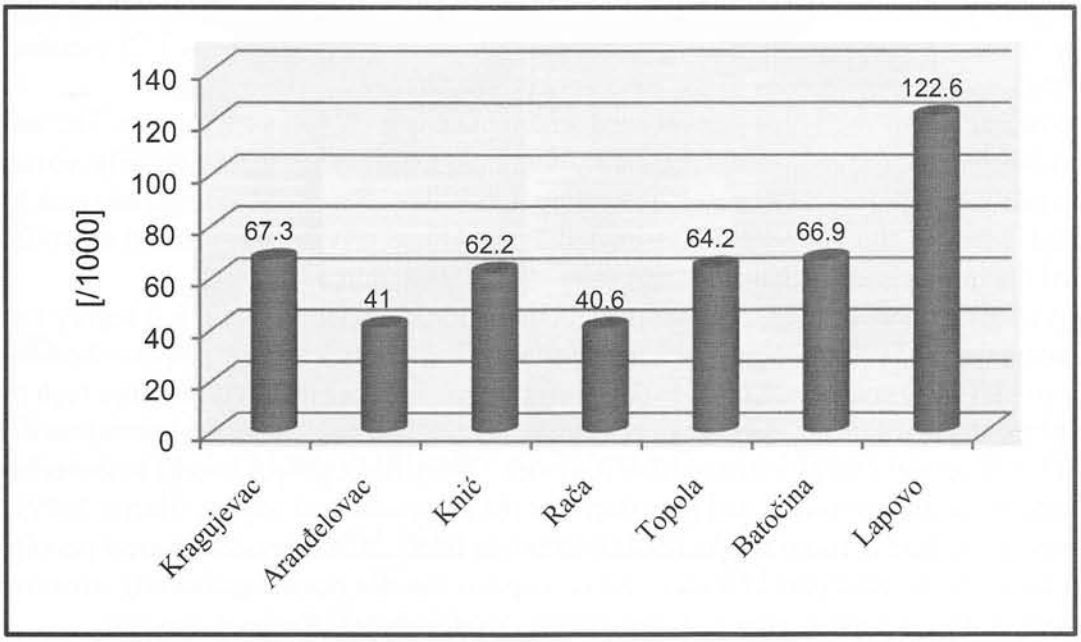

Figure 3: Šumadija District Municipalities – 2004 Mortality Rate

aquifer of the Velika Morava and Lepenica rivers, with a transmissivity ranging from 1.2 to 8.7 m^2/s. This source is comprised of10 wells, of which only two are operating and have an aggregate capacity of approximately 30 l/s. As a result, quantitative issues can reasonably be dealt with by revitalizing the existing wells and drilling several new wells. However, groundwater quality is a much larger issue. Abstracted groundwater is loaded with nitrates and nitrites, as well as with manganese (15 times exceeding quality guidelines) and iron (Fig. 4). The problem is complex and multifaceted (no organized sewage system, municipal landfill, train washing facility and agricultural activities in the infiltration zone; and illegal gravel extraction facilities which exposed the alluvial aquifer to excessive pollution).

Figure 4: . GW sample collected from an observation well – visualization of elevated iron concentration
a – Immediately upon sampling; b – 10 minutes later
c – 20 minutes later (with a couple of days "old" reference sample); d – 30 minutes later (with the reference sample).

A new water supply source Skela is due to be opened. However, in the absence of responsible planning, a scenario similar to Garevina might be expected. Still, neither of the two sources is a long-term water supply solution, since the alluvial aquifer is exposed and constantly threatened by pollution.

Traffic growth is an alarming issue worldwide. It generates most of the CO, NO_x and VOC emissions and its share of emissions has rapidly increased in the past 30 years. Since Lapovo exhibits a constant population decline, road traffic in the inner municipal zone is not supposed be a threat. The biggest and most significant problem is railway traffic, since the train washing facility is situated in the infiltration area of the water supply source. Additionally, the condition of the rails is unacceptably poor. Besides passengers, the railway line is used for freight traffic so excessive pollution is a major concern. Another traffic issue is the international highway E75, running across the infiltration zone, which adds to the excessive pollution threat.

Waste management is another critical area where management did a major role. The municipal landfill is located in the alluvium and constantly contaminates the source. Additionally, no organized sewage system is in place due to a lack of funding. Only about 5% of the sewage network has been completed. Most of the households (estimated at 70%) use private substandard cesspools. It is estimated that municipal wastewater constantly "feeds" the source.

Energy consumption, as in other economies in transition, is a critical issue: it is highly inefficient and causes severe environmental problems resulting from high levels of sulphur dioxide (SO_2), nitrogen oxide (NO_x) and carbon dioxide (CO_2) emissions. The housing sector offers a high potential for energy savings. In general, short-term conservation and efficiency measures are estimated to save at least 15% in annual energy consumption (Lujanen 1996). Also, proper energy resource selection can be crucial for energy saving and help decrease the environmental impact (Harris 2009).

The green structure is receiving increasing attention lately. It is supposed to meet people`s need for recreation and to be a part of nature. Since Lapovo has not been significantly urbanized, this component of the ecological aspect of sustainable development is the least concern.

RESEARCH METHODS

For groundwater investigation purposes, a hydrodynamic model was generated using Processing Mod-Flow open-source software. The research area was schematized in steady state, as a 6.2 by 8 km orthogonal network, with 10,092 fields made up from 87 rows and 116 columns. This field setup and density were assumed to be accurate enough for the goal of the model and the scope of the work. Initial schematization was performed with a square, 100 by 100 m cell network, in 62 rows and 80 columns. Then the network was densified around the Garevina and Skela source areas, keeping in mind the variable network rule that dimensions of adjacent cells should not differ by more than 50% (Kresic, 1997).

The model's cross-section had two 2 layers. Layer thicknesses were generated in Golden Software Surfer, using the research area DEM as a basis.

Groundwater flow area was finite by impermeable environment (Fig. 5). The alluvial aquifer was modeled as a 5 to 12 m thick shelf, thickening as rambling from the rivers. The cover was represented by a layer with lower permeability, recharge and effective porosity values. The Velika Morava and Lepenica rivers were modeled as constant head boundary (ϕ=const).

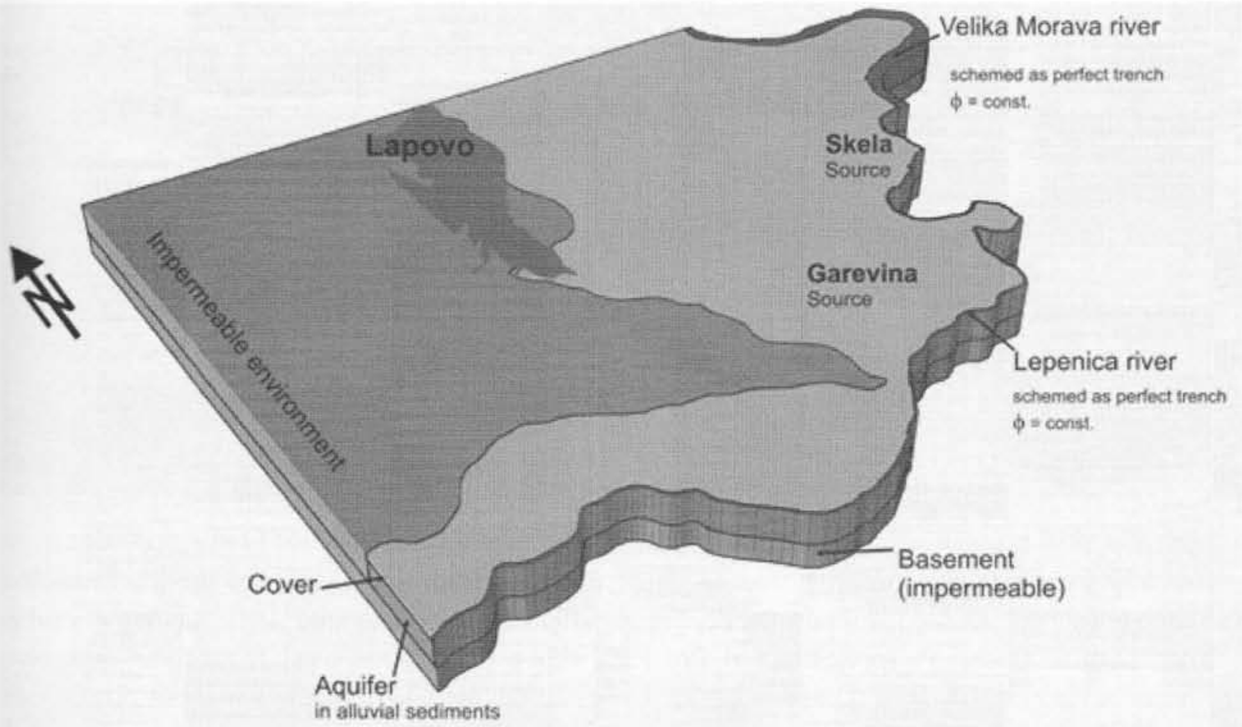

Figure 5: Conceptual Model

RESULTS

The starting point of the model was the active Garevina source (2 production wells yielding 15 l/s each). Calibration produced approx. filtration coefficient values in different areas (Tab. 1).

Table 1: Model-calibrated approx. Kf values

Area	Kf Value [m/s]
Alluvium in source areas	7.5×10^{-4}
Alluvium away from sources	4×10^{-4}
Alluvium at contact with impermeable rock	2×10^{-4}
Cover	10^{-5}

In general, calibrated values matched those obtained from testing of each well at both sources, so the model could be accepted as representative. Afterwards, it was used to compare the current (Fig. 6) with the planned abstraction situation (Fig.7), as well as to simulate two of the largest pollutant carriers in the research area: the municipal landfill and the train washing facility. The model addressed the above- mentioned pollutants because they represented the largest environmental threats. On the other hand, their locations were defined, making it possible to model them.

Pollution from the disorganized sewage system, agricultural activities in the infiltration zone and illegal gravel extraction facilities were not addressed in the model.

The planned scenario included the activation of the new source, Skela, and the shutting down of Garevina. Skela was modeled with 6 production wells yielding 15 l/s each. The planned yields are realistic regarding hydrogeological setting in the Skela source alluvium. Based on the planned configuration, there is an apparent hydraulic head change in the research area: the shutting down of Garevina caused increased groundwater flow towards Skela (Fig. 7).

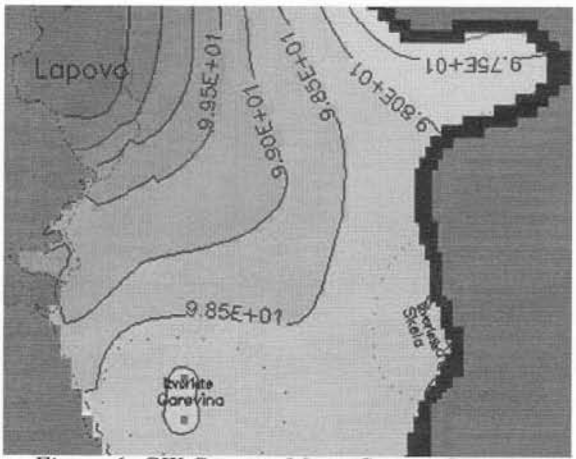

Figure 6: GW Contour Map - Current Situation

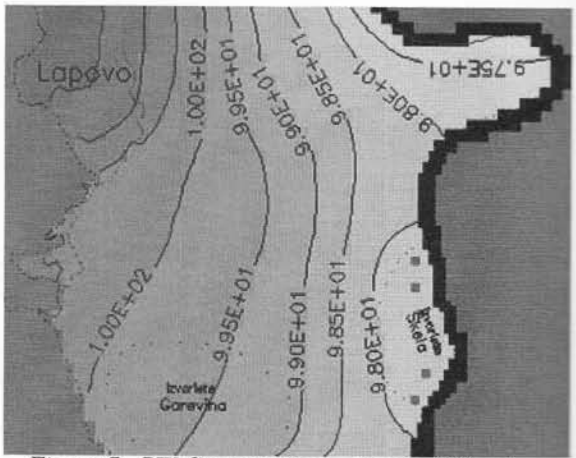

Figure 7: GW Contour Map - Planned Situation

Causally, excessive pollution risk rose up. Since pollution from the landfill and the train washing facility is constant, increased groundwater flow might affect that in certain time step it gets to the source.

The "particle tracking" application of PM-Path sub software was used to analyze excessive pollution in the research area (Guiguer 1997). To verify the model, simulation was performed first with the current abstraction situation (Garevina on / Skela off) and one year was set as the time step.

Pollution from the train washing facility reaches the source area after five time steps/years (Fig. 8). After 19 time steps, pollution from the landfill reaches the source area as well (Fig. 9). The situation shown can be accepted as realistic, since in real time the pollution has already "arrived" at the source area.

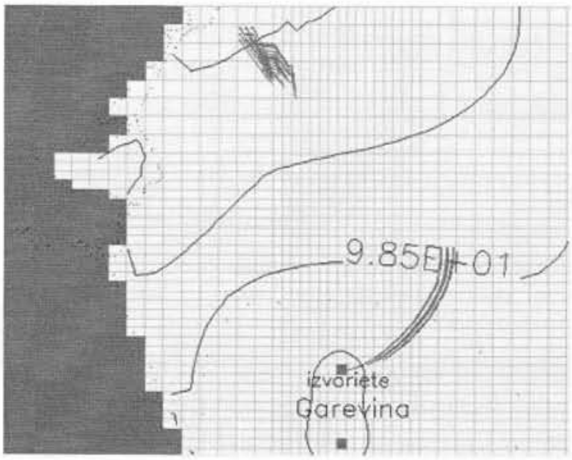

Figure 8: Particle Tracking of Pollutants
Garevina switched on / Skela switched off
After 5 Time Steps

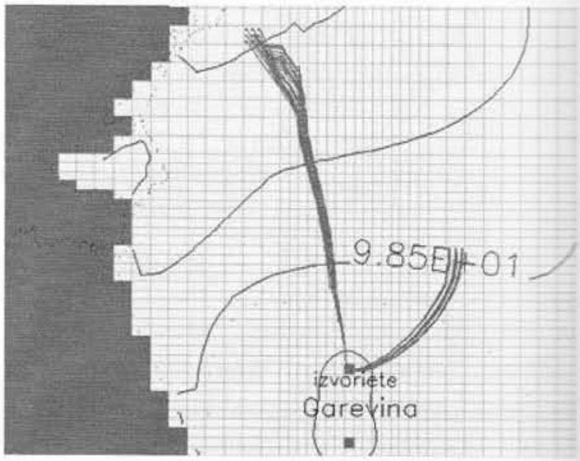

Figure 9: Particle Tracking of Pollutants
Garevina switched on / Skela switched off
After 17 Time Steps

After the current situation, the simulation of the planned situation showed that pollutants will reach the Skela source area: from the train washing facility, after 10 time steps (Fig. 10); and from the municipal landfill, after 27 time steps (Fig. 11). Apparently, the Skela source will face the same problems as Garevina has been facing for years, if the abstraction plan remains unchanged.

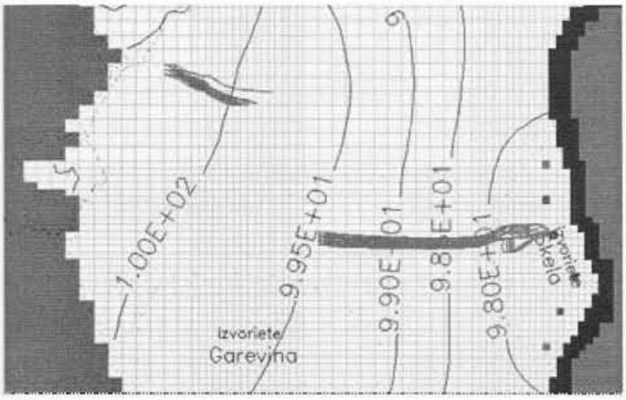

Figure 10: Particle Tracking of Pollutants
Garevina switched off / Skela switched on
After 10 Time Steps

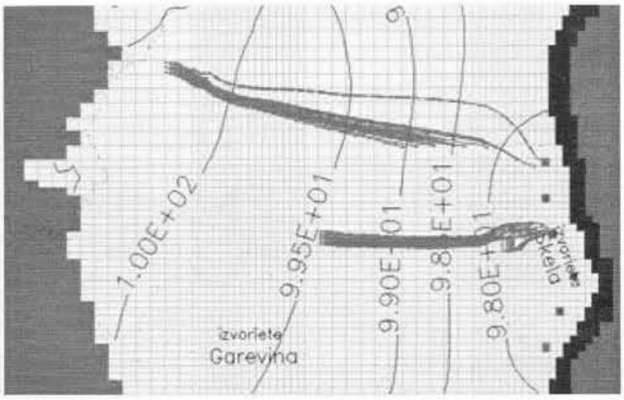

Figure 11: Particle Tracking of Pollutants
Garevina switched off / Skela switched on
After 27 Time Steps

The model was then used to manage research area groundwater flow conditions. The idea was to use the Garevina source to draw groundwater away from Skela, in fact to use it as a hydraulic barrier (Figs. 12 and 13).

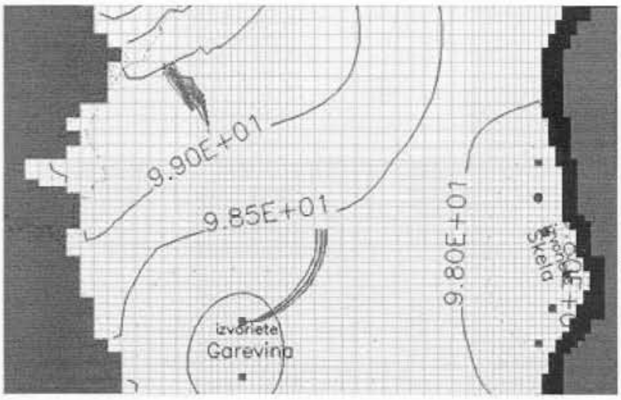

Figure 12: Particle Tracking of Pollutants
Garevina switched on / Skela switched on
After 6 Time Steps

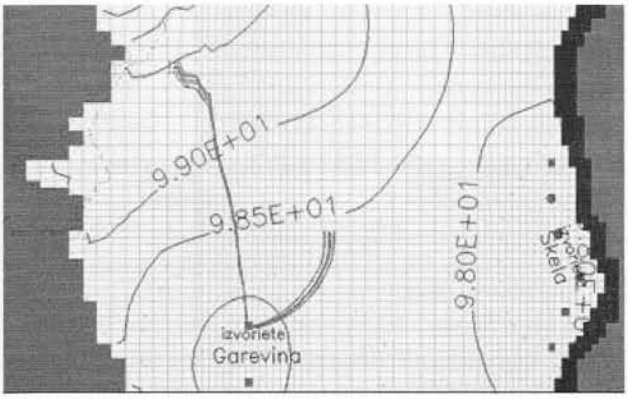

Figure 13. Particle Tracking of Pollutants
Garevina switched on / Skela switched on
After 19 Time Steps

The simulation showed that leaving Garevina on affected groundwater flow so pollution from train washing facility and municipal landfill did not get to the Skela source area neither after 6, 19 nor 100 years (which was set as maximum number of time steps).

CONCLUSION

The work presented in the paper was an attempt to use common hydrogeological research methods for general groundwater management. The idea of leaving the Garevina source active so that it can "defend" the Skela source from potential excessive pollution turned out to be a scientifically justified option. However, the environmental problems in the research area are slightly more complicated then represented with the model, because pollution from the disorganized sewage system, agricultural activities in the infiltration zone and illegal gravel extraction facilities were not addressed.

Investment in sewage system construction and water system revitalization would be a major burden on the budget of Lapovo. Nobody can stop agricultural activities, even in the infiltration zone. Illegal gravel extraction should be manageable.

Inconsistent planning at the time Lapovo was being developed left too many problems for the current municipal management to handle. Environmental problems should be approached then differently. The task ahead is to set a solid basis for the future, following ECE`s guidance for the ecological aspect of sustainable development, forming a proper data base for the five previously mentioned components:

- The fresh water resources data base should, besides mapping the currently used alluvial aquifer, consider other options such as an aquifer in Neogene sand, as well as limestone;
- The traffic data base should consider the international railway and highway as possible sources of excess pollution, such that zones where the road/railway track is not in a good condition could be treated as zones with a higher excessive pollution probability;
- The waste management data base should start out as a spatially-defined pollutants cadastre;
- The energy consumption data base should treat groundwater as energy;
- The green structure data base should treat soil properties for certain plants (Danijels 2009);

This would lead to the ability to combine and overlap all layers. The idea is to build a model with a well-thought-out algorithm for layer calculation in order to obtain a qualitative output as a basis for sustainable municipal planning/management (Kukurić, 1999). The model should have the ability to offer a proposal for urban development of the Lapovo Municipality, because only a multisectoral approach to problem solving can contribute to ecological sustainability (De Žarden 2006).

According to ECE, "…environmental problems cannot be dealt with merely by upgrading technology…"; public values and everyday habits need to change.

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