Analysis of water management measures in the Dovine River Basin, Lithuania

Possibilities to restore a natural water regime

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ABSTRACT

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The Zuvintas Lake, located in southern Lithuania in the basin of the Dovine River is one of the biggest lakes and oldest nature reserves of the country. Both the lake as well as the adjacent wetland is a potential Site of Community Interest (SCI) according to the EU Habitats Directive. However, the changes in the hydrology of the Dovine River Basin, because of large scale melioration and water management works carried out in the 20th century, have significantly changed the water regime as well as a decrease in biodiversity of Zuvintas Lake and surrounding wetlands. In order to prevent the ongoing deterioration of Zuvintas Lake and adjacent wetlands solutions have to be found at a basin level. Therefore, various scenarios to evaluate the impact of water management alternatives in the Dovine River basin have been analyzed to get insight in the impact of changes on the water regime in Zuvintas Lake and adjacent wetlands. For these scenarios the SIMGRO model was used.

Keywords: The Dovine River, Zuvintas Lake, SIMGRO model, wetlands, Lithuania.

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Contents

Preface

The work presented in this report was carried out as part of the PIN-MATRA project "Management and Restoration of Natura 2000 sites through an Integrated River Basin Management Plan of the Dovine River" funded by the Dutch Ministry of Agriculture, Nature and Food Quality and the Dutch Ministry of Foreign Affairs. The first author was working for two months in 2005 at Alterra as a research guest from the Department of Water Management, Lithuanian University of Agriculture.

During a time span of fourteen months the hydrological model of the Dovine River Basin was build and various water management alternatives to restore natural water regime in the basin were evaluated. This was only possible to succeed because of the great help of a number of persons at various organisations. The authors are grateful for the support of the Public Agency "Nature Heritage Fund" (Lithuania); the Lithuanian Geological Service, the Administration of Zuvintas Biosphere Reserve (Lithuania); the Lithuanian Institute of Geology & Geography; the Agriculture Department of Marijampole Municipality (Lithuania); the Water Management Department of the Lithuanian University of Agriculture; Wageningen International (formerly International Agricultural Centre – IAC) (The Netherlands) as well as to the Department of Water and Climate of Alterra.

Summary

The Zuvintas Lake located in the basin of the Dovine River, southern Lithuania, is one of the oldest nature reserves of the country. Despite the inflow of nutrients and related eutrophication, it is still one of Lithuania's most significant nature reserves and both the Lake as well as the adjacent wetland is a potential Site of Community Interest (SCI) according to the EU Habitats Directive. Once designated as SCI Lithuania is obliged to maintain the conservation status of the site and species for which the site is designated and to make sure that the favourable conservation status is achieved or maintained. There are three main parts of the Zuvintas Biosphere Reserve: 1) the Zuvintas Lake itself, 2) the adjacent bogs and fen meadows and 3) the Amalvas wetland.

The changes in the hydrology of the Dovine River Basin because of large scale melioration and water management works in the 20th century have caused the decreasing biodiversity of Zuvintas Lake. These works included the building of weirs and sluice gates at the outlets of some lakes (including the Zuvintas lake) to retain spring runoff, regulation of the river Dovine itself, melioration of the Amalvas wetland downstream of Zuvintas Lake and intensive agriculture and fish-breeding activities upstream Zuvintas. The biodiversity of the Amalvas wetland has significantly been impacted by drainage and land reclamation works during the last thirty years as well. The basic impediment to find a solution for the ongoing deterioration of the Zuvintas Lake and adjacent wetlands have been the lack to consider the Lake as an integrated part of the Dovine River basin and to acknowledge that solutions for the Zuvintas Lake have to be found at a basin level. Therefore, various scenarios including the removal of sluice gates and restoration of outflow from Simnas Lake through the old Bambena River meander as well as possibility for blocking drainage ditches around Zuvintas and Almalvas wetland areas have been analyzed.

For such a complex system it required the use of a combined groundwater and surface water model to predict the effect of measures on a basin scale. For such situations the SIMGRO model was developed. The model simulates the flow of water in the saturated zone, the unsaturated zone and the surface water. The model is physically-based and therefore suitable to be used in situations with changing hydrological conditions. Five different scenarios were modelled. The present situation has been considered the reference scenario and different management situations were compared to it.

Evaluation of the results from the simulations have shown that elimination of the sluice gates in Dusia, Simnas, Zuvintas and Amalvas Lakes would result in significant water level lowering. Therefore, the entire naturalization of the hydrological regime in Zuvintas Lake by removing sluice gates built on the Dovine River is impossible. Such measure would destroy the lake. When striving for the least partial naturalization of the water regime the reconstruction of the sluice gates is necessary.

Restoration of the outflow through the old Bambena River meander downstream of Simnas Lake would be an effective measure when trying to achieve naturalization of water level regime in Simnas Lake. This measure can also activate the retention of biogenic substances (phosphorus in particular) in the floodplain of the lakeside.

The encroachment of scrubs and trees in the complex of Zuvintas and Amalvas wetlands significantly lowers the groundwater level. The highest impact is estimated for pine forest during summer season. After the removal of the trees the water level can rise from 0.03 m up to more than 1.0 m. The rise of groundwater level at the outskirts of Zuvintas and Amalvas wetlands can be achieved by raising the water levels in the ditches by means of small dams or bars. Such measure would raise the groundwater level by 0.60 to 0.70 m on average on the northern, north-western and the north-eastern edges surrounding Zuvintas wetland. The introduction the such small dams can affect the territories situated at a distance from 100 to 1000 m.

The entire naturalization of water regime in Amalvas polder is possible only after the removal of the pumping station and the restoration of the direct connection with Amalvas Lake. Consequently, the water regime in the polder would be directly related to the water level fluctuations in the lake. Partial and periodical waterlogging is likely to occur. During summer season the groundwater level in the polder would be close to the ground surface. Agricultural conditions would worsen significantly.

1 Introduction

1.1 Background information

The Dovine River Basin covers an area of 589 km² and is located in the southern part of Lithuania (Fig. 1). The basin is the right tributary of the Sesupe River consisting of a network of rivers and water bodies formed by five big lakes (Dusia 23.3 km^2, Žuvintas 9.3 km^2, Simnas 2.4 km^2, Giluitis 2.4 km^2 and Amalvas 1.9 km^2) and a number of rivulets and small ponds. Most of the surrounding areas are productive agricultural lands (productivity is higher than the average of the country). The forest cover is scarce, i.e. approximately 16% of the area (the average in Lithuania – 33%).

The Dovine River Basin is an important area because it holds one of the most important and meanwhile most threatened nature reserves of Lithuania, the Žuvintas Biosphere Reserve. This reserve was established in 2002 and embraces the Žuvintas State Nature Reserve (founded in 1937), and the Žaltytis and Amalvas botanical-zoological reserves. The total area of the Biosphere Reserve is 18489 ha and includes both the Žuvintas and the Amalvas Lakes.

Žuvintas Lake is one of the biggest lakes and oldest nature reserves of Lithuania. Although Žuvintas has suffered severely from eutrophication it is still one of Lithuania's most significant nature reserves partly for historical reasons and partly also because of its extent. In the past the Lake was good example of an eutrophic lake but in the current situation only small parts of the lake qualify to be designated under the Habitats Directive (habitat type 3140) and its conservation status is far from favourable. In the bigger part of the Lake this habitat type has disappeared due to the inflow of nutrients while it also does not qualify for any other habitat type. The Lake in addition is designated under the Birds Directive because 12 bird species from the EU Birds Directive are found in Žuvintas SPA. In geomorphological terms the lake is unique and there is no other lake of this kind in Lithuania. Next to the Žuvintas Lake also located in the Dovine River Basin various areas are proposed to be designated as Natura 2000 site either under the Birds Directive or under the Habitats Directive. The most important habitats relate to the presence of bog and mire species.

The basic impediment to find a solution for the ongoing deterioration of the Žuvintas Lake and adjacent wetlands has been the lack to see the Lake as an integrated part of the Dovine River basin and to acknowledge that solutions for the Zuvintas Lake have to be found at a basin level.

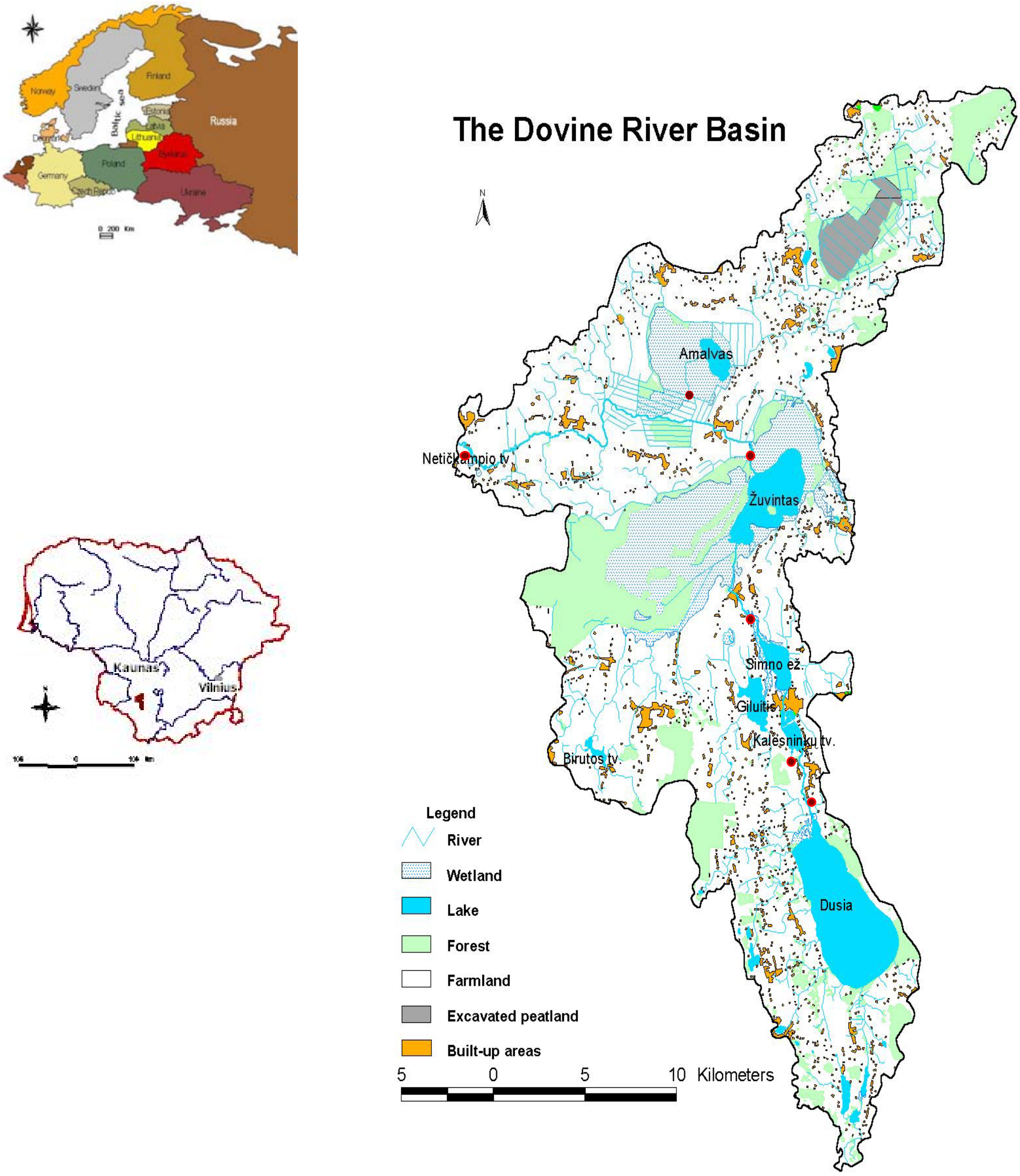

Fig.1 Location of the Dovine River basin along with sluice gates (red dots)

The Amalvas wetland complex is influenced by human activities to an even higher extent than the Žuvintas Lake. Draining ditches cover almost half of the wetland complex, excavated during the Soviet period in the late 80-ties of the last century, when the area was transformed from a bog area into pastures and hay-producing meadows. The area drained covers 2160 ha. Today most of the drained wetlands (peat soils) have been abandoned and overgrown by a dense shrub cover. The "untouched" parts of the Amalvas have become drier subsequently overgrown by shrubs and trees. After its reclamation in the 1960-ties a part of the Amalvas area was designated as a winter polder with meadows and pastures. As a result of the reclamation the groundwater level in the Amalvas polder and in the north-western part of the Amalvas wetlands declined by more than 2.0 m. As a consequence of the lower water table subsidence of the ground level took place. The water level in the polder is managed through a pumping station which is at present in bad condition and needs to be renovated.

From upstream to downstream the various stretches of the Dovine river bear different names: the upper part of the river (headwaters) is called Sutre (from the beginning till the Lake Dusia), from Lake Dusia till Lake Simnas – it is called Spernia, from Lake Simnas till Lake Žuvintas – it is called Bambena, and from Lake Žuvintas till the fall to Šešupe river – Dovine. All areas in the Dovine River Basin are hydrologically linked and measures taken in one part of the basin impact the situation in another part of the basin. Both the obligation to maintain the favourable conservation status of the Žuvintas Lake, adjacent wet grasslands and bogs (based on the EU Habitats Directive) and the obligation to restore the reference situation of the Dovine river (according to the EU Water Framework Directive) make the area an excellent study site for integrating of the protection and restoration of nature values of European significance into integrated river basin management.

1.2 Description of problems

The predominantly fertile soils of the Dovine River basin stimulated the extension of agriculture along with water management activity. During the second half of the twentieth century, the water regime of the Dovine River and its basin was significantly altered (Taminskas, 2004). Many rivulets were canalized. A number of dams were built and large bog and fen areas were drained.

The Dovine River discharges into the Sesupe River at Marijampole town, which is located 25 km downstream of Žuvintas Lake. In the second half of the twentieth century with the growth of industry a shortage of water in the Sesupe River appeared. In order to solve the lack of clean water in summer, sluice gates were built on the Dovine River at the outlets of Dusia, Simnas and Žuvintas Lakes to accumulate part of spring runoff. In addition to that, a small hydro-power station was built in the lowest reaches of the Dovine River at Netickampis. The dams for the Dusia, Simnas and Žuvintas lakes were meant as the first stage of a water management plan for the entire area. Fortunately, other stages (redirection of water from other basins) remained un-realized. In 1992, after introduction of a sewage treatment plant, the system of artificial water accumulation in the lakes lost its value for the Marijampole town. In the 80-ties of the last century, the hydrology of the area again was altered due to the execution of large scale amelioration works: northern and southern parts of the Amalvas wetland (to the north-east from Zuvintas Lake) were drained and long sections of the Dovine watercourse were channelized.

The impact of agricultural activity in the river basin on the water quality became more and more evident. Pollution from Simnas town and the other villages, as well as from non-point pollution sources further deteriorated the quality of the water and accelerated eutrophication process in Žuvintas and Simnas Lakes. During the second part of the last century due to intensified drainage activity about 36% of the Žuvintas Lake basin area was ameliorated. In 1972 after construction of the sluice on the Spernia River 0.6 km downstream of Dusia Lake the average water level of the lake raised by 0.43 m and the area increased by 17 ha. This higher water level accelerated shore abrasion. In 1965 after constructing a dam along with drop inlet spillway 4.2 km downstream of Dusia Lake and 3.7 km upstream of Simnas Lake the Simnas fishing ponds were established. After the constructing of sluice-gate 0.5 km downstream of Simnas Lake on the Bambena River in 1972 the average water level of Simnas Lake increased by 0.83 m and the area of the lake increased by 6.8 ha. After the construction of the sluice-gate downstream Žuvintas Lake in 1972 the water level increased up to 0.31 m. However, the area of the lake did not increase but instead decreased because of peat forming along the shores. Data from different sources shows that in 1954 the total surface area of the lake was 1931 ha while in 1961 it was only 1009.3 ha and in 2003 - 962.1 ha. During the period of 1961-2003 every year the surface area decreased with a rate of about 1.1 ha per year. The shrinking surface was also caused by the increasing area of floating islands.

Before regulation the main part of the rivers extended through wet peaty meadows and the width of the floodplains was up to 0.6 km. The floodplain of the Bambena lower reaches was even 1 km wide. During floods particles of organic and inorganic material were accumulated in the meadows. After regulation only some parts of floodplain have been flooded during the periods of peak discharge. Most part of transported sediment and nutrients accumulate in the lake.

Obvious, that the change of hydrological regime has had a negative impact on the biodiversity of the Dovine River Basin and on the Žuvintas Lake in particular. The lake is rapidly shrinking in size due to the massive overgrowth of the shore and the lake bottom. More than half of the lake surface area is covered with aquatic plants. The high nutrient concentration in sediments is the main reason for the massive growth of vegetation. The overgrowth of the lake is a natural process that started after the Ice Age, however, it is also clear that the recent pollution and nutrient accumulation has speeded up the process significantly.

Adjacent to the Žuvintas Lake are extensive bog and fen areas. Traditional hay-mowing and pasturage practices were widely applied in these areas for a long period. During the last decades abandonment of the fen areas has occurred resulting in transformation of open fen and wet meadow areas into wet forests. Unless management is taken up again this process will cause the loss of valuable areas in the next decades. Adding to the shrub and tree encroachment in the bog areas are the changes in the hydrology of the Žuvintas Biosphere Reserve.

1.3 Objectives

This study was part of the PIN-MATRA project "**Management and Restoration of Natura 2000 sites through an Integrated River Basin Management Plan of the Dovine River**" funded by the Dutch Ministry of Agriculture, Nature and Food Quality and the Dutch Ministry of Foreign Affairs. The general objective of the research was to evaluate the impact of various water management alternatives in order to reach a more natural water regime in the Dovine River Basin. The research was mainly focused on the possibilities to achieve as natural as possible flow pattern in the Dovine River as well as to restore hydrological regime in Zuvintas Lake and adjacent wetlands.

2 Methods and data

2.1 Modelling methodology

For such a complex system as the Dovine River Basin it required the use of a combined groundwater and surface water model to predict the effect of measures. Therefore, the SIMGRO model was used. The model simulates the flow of water in the saturated zone, the unsaturated zone and the surface water (Fig. 2.1). The model is physically-based and therefore suitable to be used in situations with changing hydrological conditions.

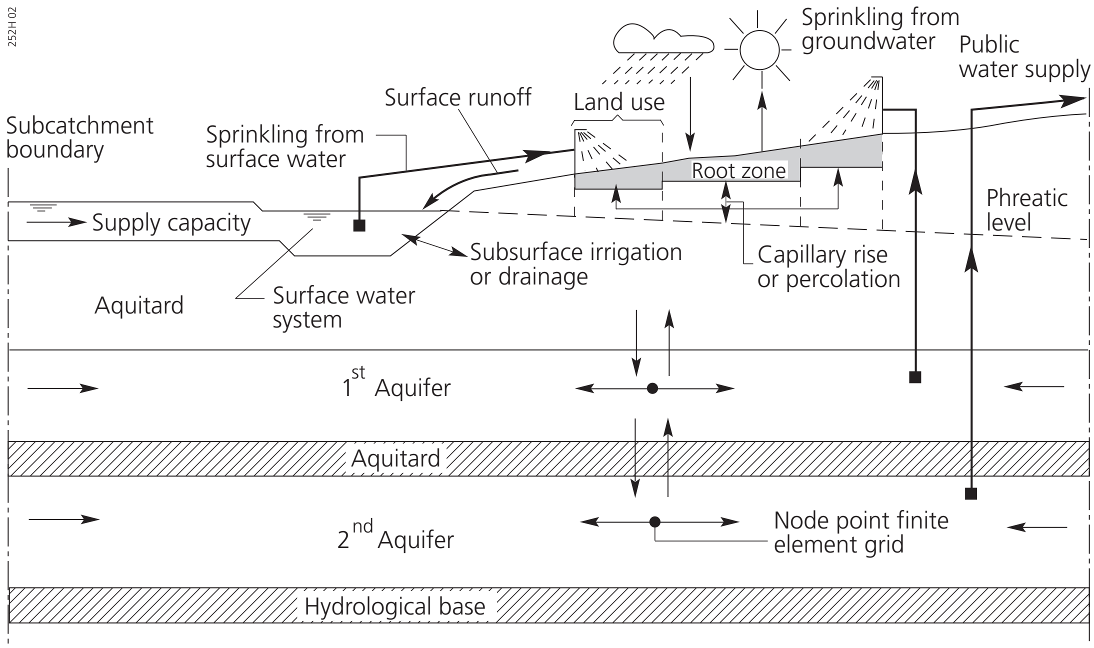

Fig. 2.1 Schematisation of water flow in the SIMGRO model

SIMGRO (SIMulation of GROundwater and surface water levels) is a distributed parameter model that simulates regional transient saturated groundwater flow, unsaturated flow, actual evapotranspiration, sprinkler irrigation, stream flow, groundwater and surface water levels as a response to rainfall, reference evapotranspiration, and groundwater abstraction (van Walsum et al, 2004; Querner, 1997; Nauta et al., 2005).

To model regional groundwater flow, as in SIMGRO, the system has to be schematised geographically, both horizontally and vertically. The horizontal schematisation allows input of different land uses and soils per subregion, in order to model spatial differences in evapotranspiration and moisture content in the unsaturated zone.

2.1.1 Groundwater flow

In SIMGRO the finite element procedure is applied to approach the flow equation which describes transient groundwater flow in the saturated zone. A transmissivity is allocated to each nodal point to account for the regional hydrogeology. A number of nodal points makes up a subregion. The unsaturated zone is represented by means of two reservoirs, one for the root zone and one for the underlying soil. Evapotranspiration is a function of the crop and moisture content in the root zone. The measured values for net precipitation, potential evapotranspiration for a reference crop (grass) and woodland are input data for the model. The potential evapotranspiration for other crops or vegetation types are derived in the model from the values for the reference crop by converting with known crop factors. The paved part of the urban area is assumed to have no evaporation, while the unpaved part is considered as grass.

2.1.2 Surface water flow

The surface water system is often a dense network of watercourses. It is not feasible to explicitly account for all these watercourses in a regional simulation model, yet the water levels in the smaller watercourses are important for estimating the amount of drainage or subsurface irrigation, and the water flow in the major watercourses is important for the flow routing. The solution is to model the surface water system as a network of reservoirs. The inflow of one reservoir may be the discharge of the various watercourses and ditches, runoff and water from a sewage treatment plant. The outflow from one reservoir is the inflow to the next reservoir. The water level depends on surface water storage and on reservoir inflow and discharge. For each reservoir, input data are required on a 'stage versus storage' relation and a 'stage versus discharge' relation.

2.1.3 Drainage

Watercourses are important for the interaction between surface water and groundwater. In the model, four drainage subsystems are used to simulate the drainage. It is assumed that three of the subsystems ditches, tertiary watercourses and secondary watercourses are distributed evenly over a finite element or subregion. These three systems are primarily involved in the interaction between surface water and groundwater. A primary system can also be included in specific nodes, to represent the larger channels in the area modelled. The interaction between surface and groundwater is calculated for each drainage subsystem using a drainage resistance and the difference in level between groundwater and surface water.

2.1.4 Snow accumulation and melting

In the SIMGRO model snow accumulation has been accounted for. The assumption is made that snow accumulation and melting is related to the daily average temperature. When the temperature is smaller than zero Celsius, snow accumulates. For temperature between zero and one degree Celsius, both precipitation and snow melting occurs: it is assumed that during day time precipitation occurs and during night time the snow accumulates (50/50%). When the temperature is higher than one degree Celsius, the snow melts with a rate of 3 mm/day per degree.

2.1.5 User interface AlterrAqua

AlterrAqua is a user interface in Arcview, developed around the SIMGRO model. The function is to make the model more user-friendly and easy accessible. The interface is a tool to use existing digital data, such as a soil map, land use map, watercourses, etc.. The input data for the model is generated in separate modules. Because AlterrAqua was developed according to Dutch environmental conditions (for example weather conditions), the default values used in standard data files and look up tables initially contain Dutch standard values. Therefore during the research changes were made in the interface to adapt the model to Lithuanian environmental conditions.

2.2 Modelling area and schematisation

A SIMGRO model application has been build for the entire Dovine basin with a size of approx 600 km^2. The land use in the basin is predominantly agriculture: about 16% is pasture and meadows, 46% is arable, 9% is woodland, 14% natural wetlands (including sparse forest) and 3% is urbanized area.

For the SIMGRO model the groundwater system needs to be schematised by means of a finite element network. The network used comprises of 4370 nodes spaced about 400 m apart. The peat layer of the Amalvas and Žuvintas bog is considered as an aquitard ranging in thickness of 2-4 m. The resistance of this peat layer is in the order of 400 days. The aquifer below has a thickness of 40-80 m and a transmissivity of about 20-65 m^2.day^{-1}.

For the modelling of the surface water the basin is subdivided in 460 sub-basins. The schematisation of the surface water further included sluice gates, weirs and the pumping station for the Amalvas polder.

2.3 Model input data

For the modelling of spatially distributed features in the Dovine River Basin using the AlterrAqua user interface, the available digital data was used. The following thematic layers were created for the SIMGRO model:

Digital terrain model (DTM) based on raster grid data. This layer was created by linear interpolation procedure taking into account topographical features (contour lines) of the Dovine river basin. Digitalization was performed by using analogue (plan-view) maps at a scale 1:10000. Other required data were: boundaries of the Dovine river basin along with sub-basins; hydrographic network; land use; geological layers and hydro-geological parameters of the river basin; soils characteristics; locations of hydraulic structures.

The mentioned above information was provided by the Lithuanian Institute of Geography & Geology (see maps in Appendix 1-5). Geological information of the Dovine River basin in digital format was provided by the Lithuanian Geological Service.

2.3.1 Meteorological and hydrological data

There are two state water level monitoring stations in the Dovine River basin – in Dusia Lake at Meteliai and Žuvintas Lake at Administration of Žuvintas BR. Daily precipitation and average daily air temperature was taken from the Lazdijai Meteorological Station for the period of 1955 up to December 2005. The maximum and minimum values of daily air temperature and the data on average wind speed for the calculation of potential evapotranspiration have been additionally collected. It was assumed that daily amount of precipitation and air temperature have distributed evenly on the entire Dovine River basin.

Mean daily discharges of the Bambena River at Azuoliniai village were measured for the period January -December, 2005. A number of single measurements in August 2004 of discharges were carried out for the Spernia, the Bambena and the Sutre rivers as well as in small tributaries of the Dovine (Kilkus, 2004).

2.3.2 Longitudinal profile and cross-section of the Dovine riverbed

Surface water input data consists of information on the main river streams, secondary water courses and drainage systems. For that purpose the dimensions of any water course had to be given: bottom width, left and right side slope of the river bed and etc. Therefore, information on longitudinal profile and cross-section of the Dovine riverbed (including sections of the Sutre, the Spernia and the Bambena rivers) before and after land reclamation activity as well as characteristics of installed hydraulic structures (sluice gates and etc.) in the river basin according to performed projects documentation was obtained from Agriculture Department of Marijampole

Municipality, Hidroprojektas Ltd., Industrial constructions design institute (PSPI) as well as from the archives of the Lithuanian Institute of Geology & Geography.

2.3.3 Soils and topography

The dominant soils are Haplic Luvisols covering one third of the basin while Gleyic Luvisols cover more than 20% of the territory of Dovine River basin. Distribution of different soil types developed on the peat is high. The soil conditions in physical and chemical terms are favourable for agriculture. The soils in the Dovine River basin are mainly developed on sandy loam (27.9%) peat (26.5%) and on light clay loam (20.7%). Sandy loam soils prevail in hilly southern part of the basin, light clay loam and peat soils dominate within the Žuvintas Biosphere Reserve.

The relief of the northern part of Dovine basin is rather flat (80-100m NN) and holds various glacial lakes. In the southern direction it changes into low glacial hilly landscape (100-190 m NN).

3 Calibration and verification of SIMGRO model

The SIMGRO model was calibrated using the available measured data in the Dovine River Basin during the period 1996-2002. Model's verification was performed using the same type of information collected for the period 2003 to December 2005.

3.1 Calibration

The model was calibrated with the available meteorological information and water levels measured in Dusia and Zuvintas Lakes. Since the management of the sluice gate openings was unknown for the analysed period, the position of gates corresponding to the measured water levels had to be determined. In addition, "stage versus discharge" (H/Q) relationship for each reservoir had to be adjusted (see Chapter 2.1.2). The initial conditions (groundwater level, soil humidity and others in calculation nodes) were determined in the approach way while carrying out preliminary simulations.

Therefore, the mentioned above parameters were adjusted such that the difference between measured and simulated water levels in the lakes reached a minimum. The statistical evaluation of simulation results is presented in Table 3.1.

The simulated water levels in Zuvintas and Dusia lakes were close to the measured ones. The average values of simulated water levels (86.82 and 106.20 m, respectively) almost coincided with measured means in both lakes during the analysed period. The maximum absolute error (*ME*) between measured and simulated quantities was bigger in the Zuvintas Lake. On the other hand, the amplitude of water level fluctuation was higher there. The root mean square error (*RMSE*) in both calculation cases was not large. *RMSE* (expressed as %) indicates the degree of over – or underestimation by the model with respect to the mean of measured values (lower limit is zero). It shows that only 16.1% (in Zuvintas) and 14.1% (in Dusia) of simulated values decline from the mean of measured ones. The coefficients of the residual mass (*CRM*) were close to zero in both cases (the CRM indicates if model simulations tend to overestimate or underestimate). The index of agreement *IA* (reflects the degree to which a model's simulations are error free) shows that the variation of simulated water levels in Zuvintas Lake fits a bit better with the measured quantity variation while comparing with the Dusia Lake. However, in both cases the *IA* showed sufficiently high degree of variation equivalence. Only in the Dusia Lake the decline of measured values from the mean (*d* criterion) was by 68% higher than the declines of simulated values from the mean of measured ones. The coefficient of determination (*d*) is not equal to the coefficient of determination applied in conventional statistics. It indicates how the dynamics in measured and simulated values agree. In the case of Zuvintas Lake, these declines are almost identical to the measured ones.

Table 3.1 Statistical evaluation of simulated water levels (model calibration)

Lake	Statistical criteria*					
	ME	RMSE	CRM	IA	d	N
Zuvintas	0.750	0.161	0.0006	0.807	0.970	2557
Dusia	0.349	0.141	0.0002	0.700	1.685	2514

* ME- the maximum absolute error; RMSE - root mean square error; CRM - coefficient of the residual mass; IA - index of agreement; d - coefficient of determination; N – number of pairs.

3.2 Verification

The main objective of verification procedure was to examine the capability of SIMGRO model based on the calibrated parameters to simulate the hydrological variables under different meteorological conditions.

3.2.1 Water levels

The water level dynamics during the verification period is shown in Figures 3.1 and 3.2. The simulations were also statistically analyzed and proved the suitability of the SIMGRO model to simulate surface water levels (Table 3.2). The means of measured (86.85 and 106.18 m, respectively) and simulated (86.83 and 106.22 m) water levels are similar for both lakes. The minimum and the peak values were evaluated accurately enough. The simulated values deviated respectively 15.9% and 12.9% from the mean measured ones. However, the simulated water level was slightly overestimated for Zuvintas Lake and underestimated for Dusia Lake (see criteria *CRM* and *d* in Table 3.2).

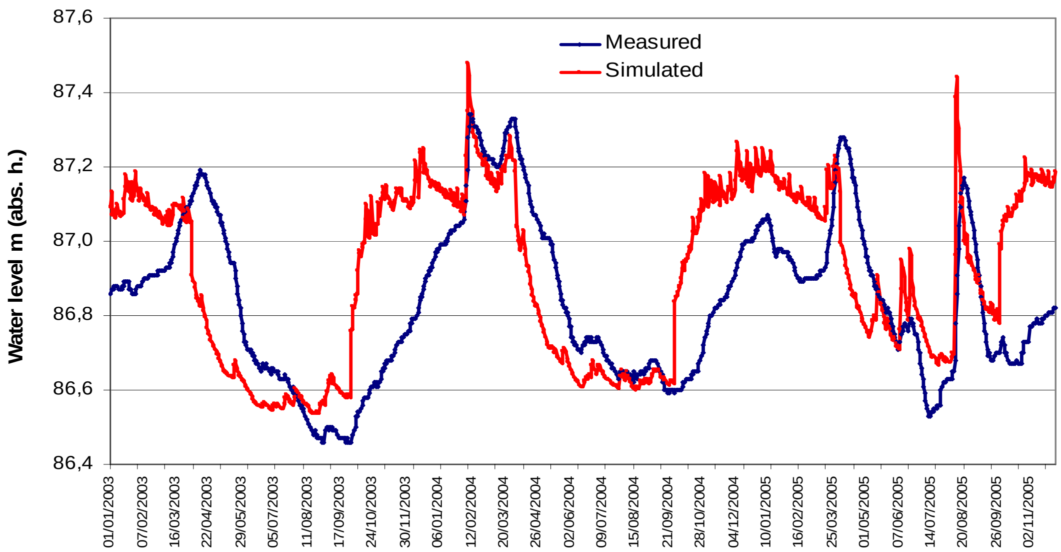

Fig. 3.1 The dynamics of measured and simulated water levels in Zuvintas Lake (verification period)

Table 3.2 Statistical evaluation of simulated water levels (model verification)

Lake	Statistical criteria					
	ME	RMSE	CRM	IA	d	N
Zuvintas	0.420	0.159	-0.0003	0.842	0.768	1065
Dusia	0.269	0.129	0.0005	0.686	1.690	1065

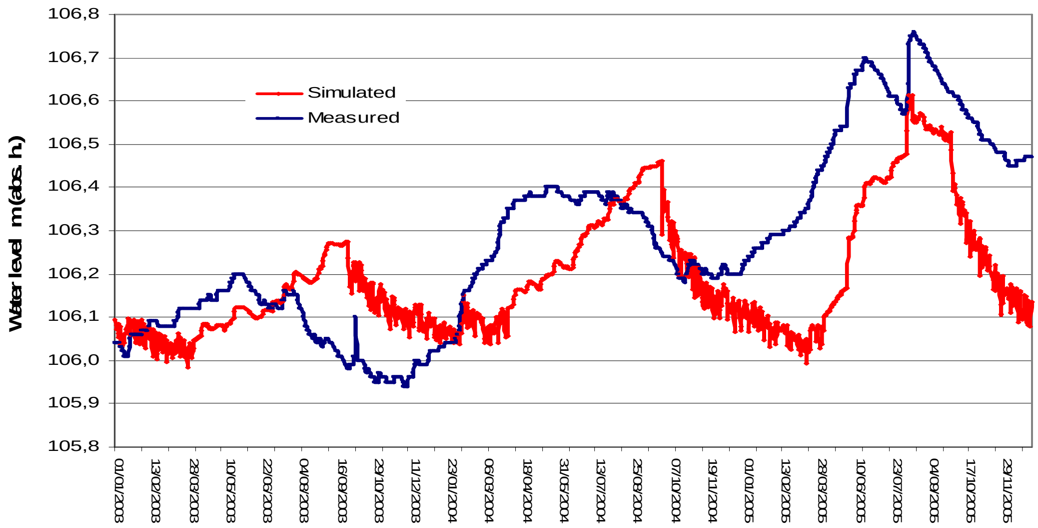

Fig. 3.2 The dynamics of measured and simulated water levels in Dusia Lake (verification period)

3.2.2 Discharges

Because of the lack of measured data the water discharge simulation results did not completely reveal the model's ability to evaluate the patterns of stream flow during different hydrological periods. However, the comparison of single measurements at 22 sites (Fig.3.3) in the Dovine River Basin with the simulated discharges showed small differences (Povilaitis, 2005).

Only the newly started continuous water discharge measurements in the Bambena River at Azuoliniai provided more comprehensive information on models ability to simulate stream flow. Comparing those daily discharge measurements for 2005 with the corresponding simulated discharges is shown in Figure 3.5. The model overestimated stream flow during winter time, however, with the decrease of inflow in April, simulated and measured quantities became close. The difference could be caused by the operations of Simnas and Dusia sluice gates. Also the water flow through the gates could be reduced in winter time due to freezing. Further more the snow accumulation and melting process could cause some differences. The overall differences between the simulated and measured discharges are considered to be acceptable.

3.2.3 Groundwater levels

The ground water table in different parts of the Dovine River Basin greatly varies because of hilly topography and due to variability of hydro-geological conditions. In the southern part of the basin, the groundwater table is found deeper, in the north-western part it occurs in shallower layers. Unfortunately no measurements of the temporal dynamics of groundwater levels at one site during the analyzed period are available. However, 38 wells measured in August-September, 2004 (Fig. 3.4) provided at least some information on the spatial distribution of groundwater tables and allowed to verify the model. The difference between all measured and simulated groundwater levels varied from 0.07 to 3.5 m. In 26 wells the differences were less than one meter and in 34 wells less than 2 meters (Fig.3.6). A problem faced by the comparison is that the observed groundwater level is for a certain location, whereas the calculated level is an average for the area associated with a nodal point.

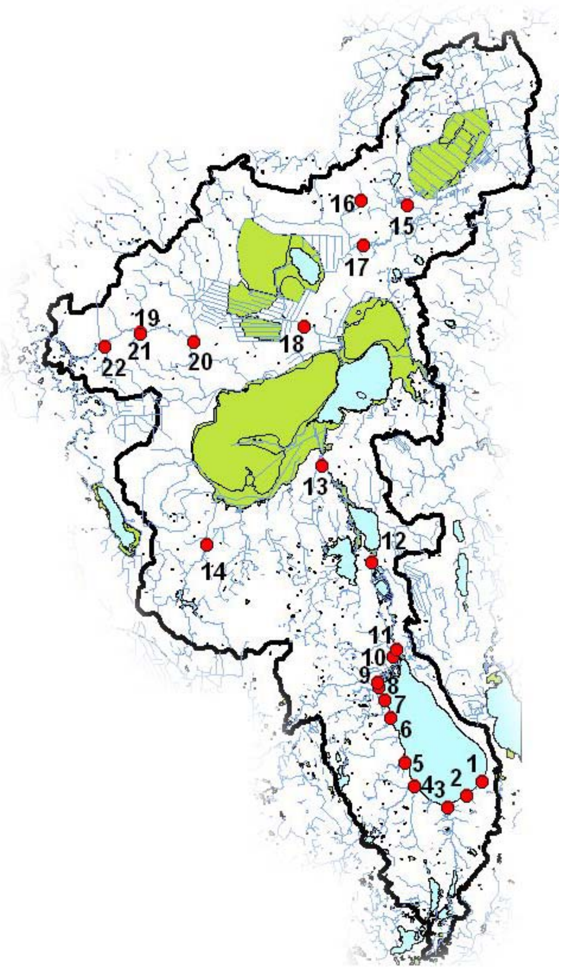

Fig. 3.3 Discharge measurement sites in the Dovine River Basin (measurement station on the Bambena River is marked with nr.13)

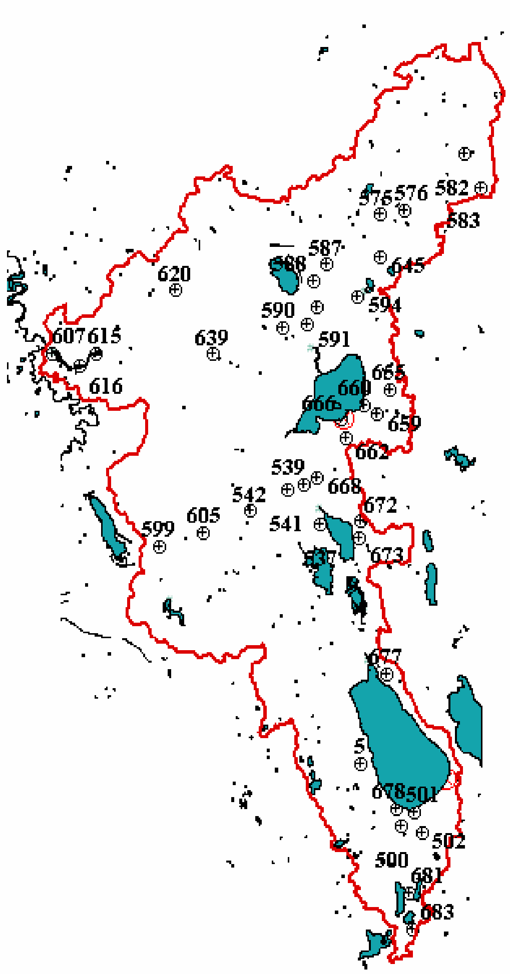

Fig. 3.4 Sites for the groundwater level measurements along with the wells numbers

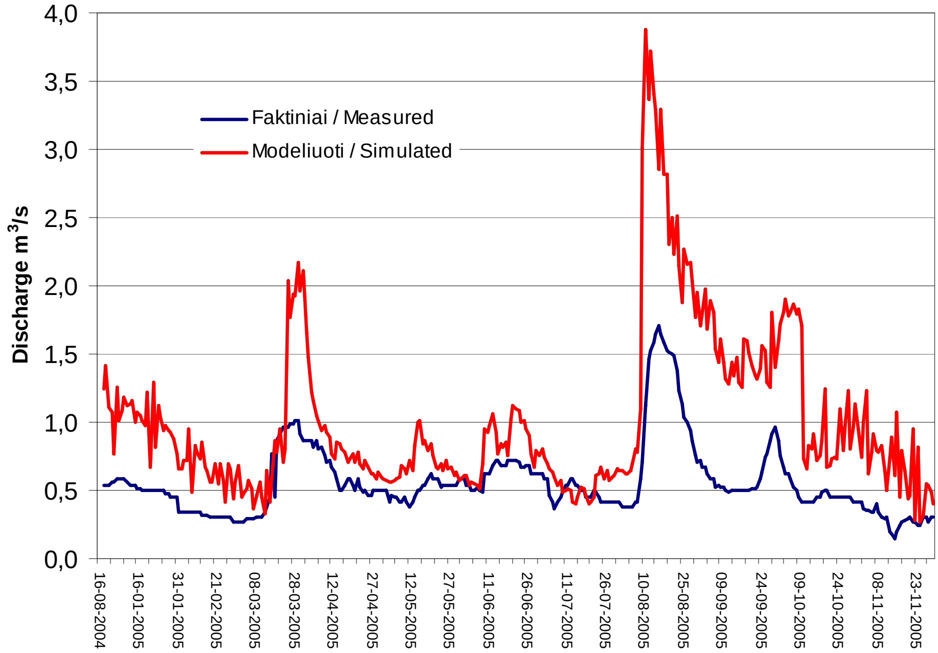

Fig. 3.5 The dynamics of measured and simulated water discharges in the Bambena River upstream Azuoliniai village in 2005

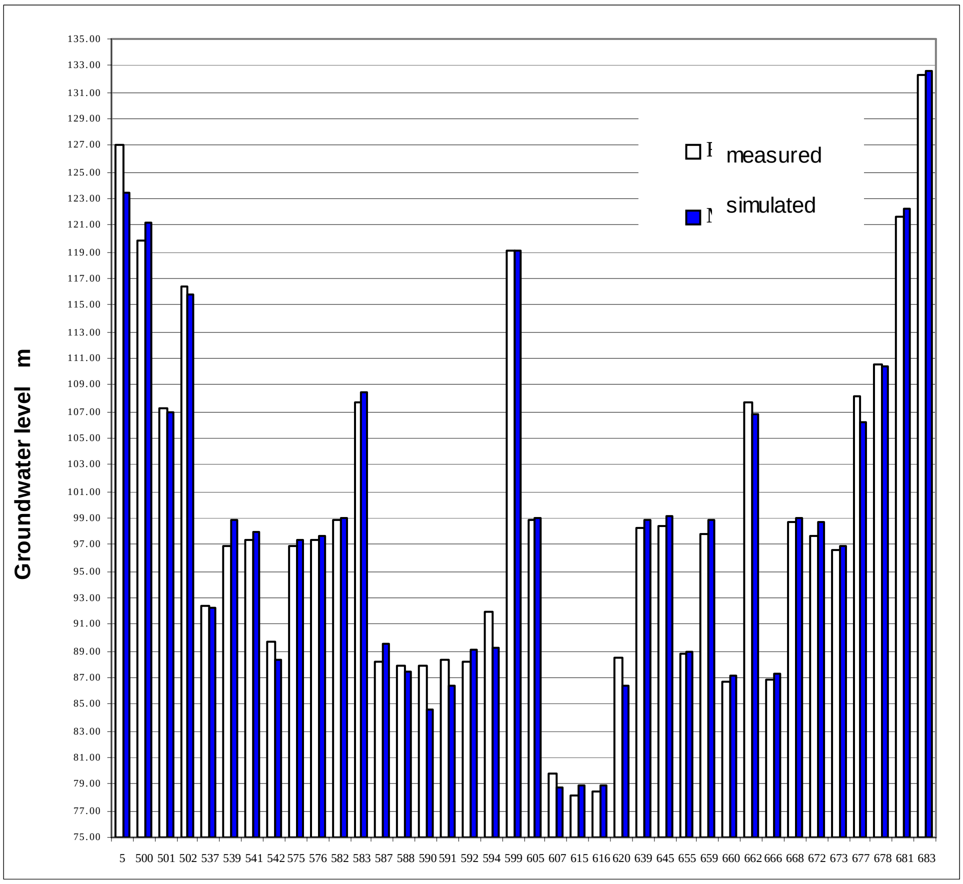

Fig. 3.6 Measured vs. simulated groundwater level (above Mean Sea Level) according to wells numbers

3.2.4 Conclusion on reliability of the SIMGRO model

The comparison of measured and simulated discharges, groundwater levels and lake water levels revealed that there were differences. However, in spite of some inaccuracies that could be also related to the errors in the measured data, SIMGRO model showed to be a useful tool to predict groundwater movement and its interactions with surface water in the Dovine River basin.

4 Scenario analysis

The water management measures focus on the entire Dovine basin, the lakes and on the Amalvas and Zuvintas wetland complexes. For the Dovine basin runoff regime should be made more natural. For Zuvintas Lake the rapid growth of water plants should be reduced by considering a more natural water level fluctuation and a reduction in the inflow of nutrients. For the Amalvas and Zuvintas wetland complex the encroachment of scrubs and trees on the bog area should be stopped. Higher groundwater levels are needed and the loss of water to adjacent reclaimed land should be reduced as much as possible.

Table 4.1 Management scenarios simulated with the SIMGRO model

Scenario	Description (main features)
0	Present situation used as reference
1	Removal of sluice gates
2	Naturalization of hydrological regime in Simnas Lake when restoring outflow through the old Bambena River meander
3	Scrub encroachment in Amalvas and Zuvintas wetlands (overgrown by scrubs and trees)
4	Blocking drainage ditches around Zuvintas and Almalvas wetlands
5	Water regime restoration in Amalvas polder

Therefore, various scenarios including the removal of sluice gates have been analyzed to get insight in the impact of changes of the river regime on the water levels in Zuvintas Lake and adjacent wetlands. Simulations were carried out daily in the period of 1995-2005 by estimating surface and groundwater levels according to the changing meteorological conditions. The list of management measures simulated with SIMGRO is given in Table 4.1. Depending on what changes may occur due to certain pressures on environment, the scenarios can simulate a "what if…" situation.

4.1 Present situation (scenario "0")

This scenario reflects present water management practices in the Dovine River Basin as well as their impact on surface water and groundwater characteristics. This scenario is based on calibration and verification results of the model. Scenario "0" is the comparative characteristic of other scenarios. It gives the possibility to judge about the impact of different water management practices on water regime in the Dovine River basin.

Simulation results showed that under the present conditions the average groundwater level during summer season occurs from 0.10 up to more than 10.0 m below the ground surface. In winter the average highest water level at different sites within the basin fluctuates from 0 to more than 7.0 m. When evaluating by the absolute height, the groundwater level in the complex of Zuvintas and Amalvas wetlands is much higher than in the surrounding areas (Figs. 4.1-4.2).

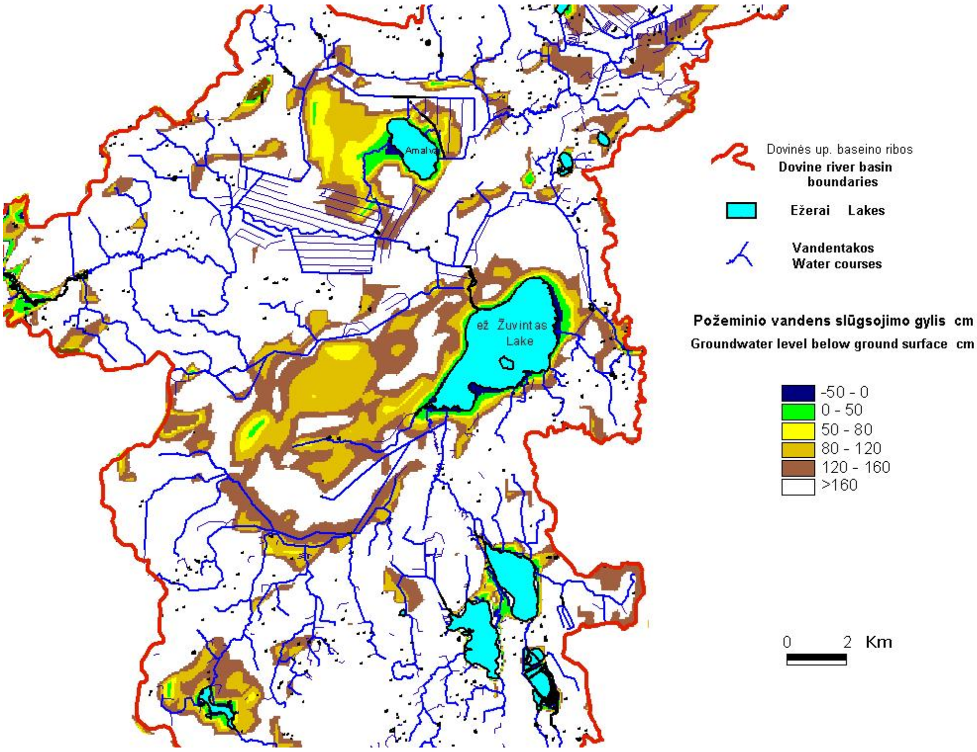

Fig. 4.1 Groundwater level in the complex of Zuvintas and Amalvas wetlands and Simnas Lake during dry period (scenario "0")

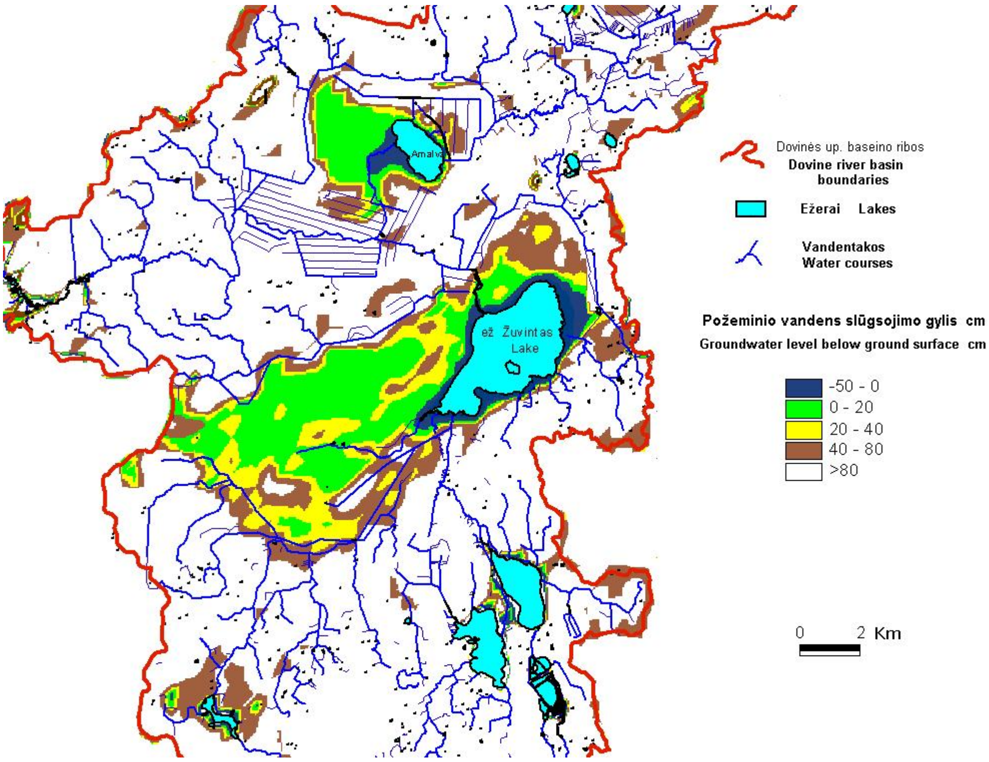

Fig. 4.2 Groundwater level in the complex of Zuvintas and Amalvas wetlands and Simnas Lake during winter (scenario "0")

4.2 The removal of sluice gates (scenario "1")

Scenario "1" reflects the changes of hydrological regime in the Dovine River Basin after the removal of sluice gates. It was not meant the physical destruction of existing hydraulic structures. The removal of sluices means free water release through the sluices without any gates. For the cases of sluices in Dusia, Simnas, Amalvas and Zuvintas Lakes, it means that the water would flow through the entirely opened gates when the altitude of the lower crest is 104.90, 90.00, 84.00 m and 84.00 m, respectively.

The results from such simulations revealed that the removal of sluice gates could result in significant undesirable water level decrease in the lakes: on the average by 50 cm in Dusia Lake, in Simnas Lake – by 140 cm, in Amalvas Lake – by 120 and in Lake Zuvintas – by 122 cm. Such decrease of water level can destroy Zuvintas Lake. The water level in the lake would drop down below its critical level. The major part of earlier water-covered area of the lake can be replaced by the land. The groundwater level can decrease by 2-100 cm in the complex of wetlands surrounding the lake (Figs. 4.3-4.4). The removal of sluice gates can influence adverse the Amalvas Lake as well. The south-western part of this lake would drain up significantly. The groundwater level in the wetlands surrounding Amalvas Lake can decrease by 50 cm on average compare to the scenario "0".

Consequently, the necessity of the damming in the lakes remains. The other important reason is to maintain the present or higher water level in the lakes in order to avoid large areas with appearing very shallow water depths.

4.3 Naturalization of hydrological regime in Simnas Lake when restoring outflow through the old Bambena River meander (scenario "2")

According to the water management project implemented in 1972 the hydrological regime in Simnas Lake was changed while installing three-hole sluice and dike at the outlet. Outflow from the lake has been diverted to artificially made 700 m length new watercourse (Fig. 4.5). Consequently, the natural 890 m length strip of the Bambena River was abandoned.

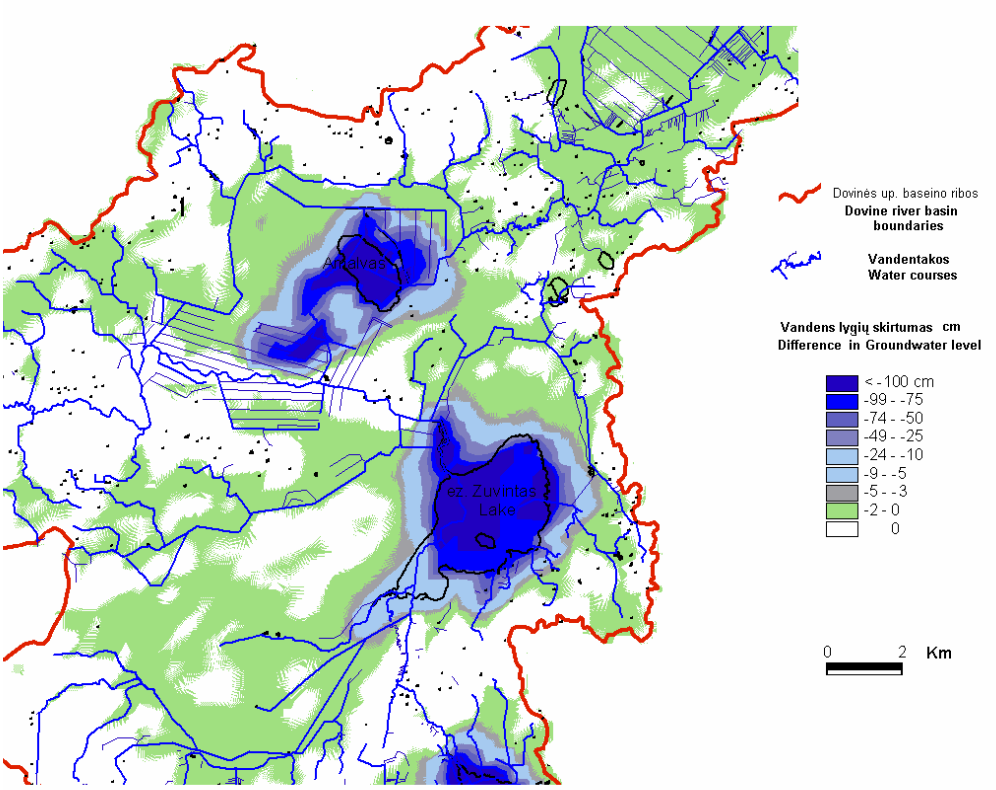

Fig. 4.3 Average decrease in surface and groundwater levels in Zuvintas and Amalvas Lakes and adjacent wetland areas during summer season (effect of the removal of sluice gates in comparison with scenario "0")

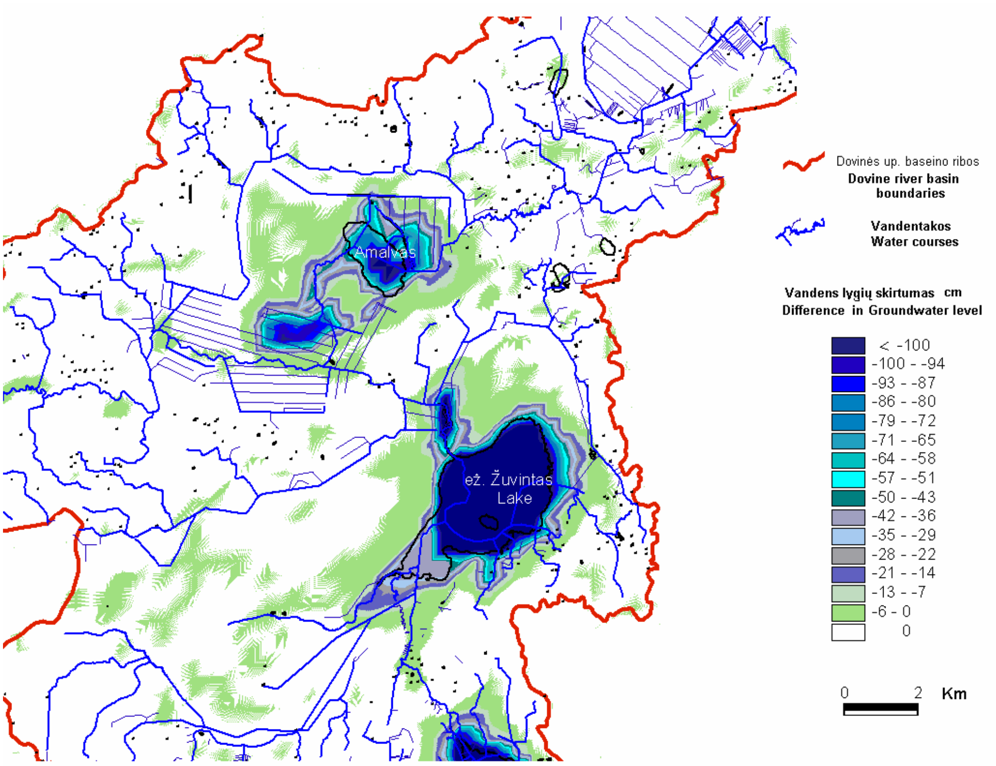

Fig. 4.4 Average decrease in surface and groundwater levels in Zuvintas and Amalvas Lakes and adjacent wetland areas during winter (effect of the removal of sluice gates in comparison with scenario "0")

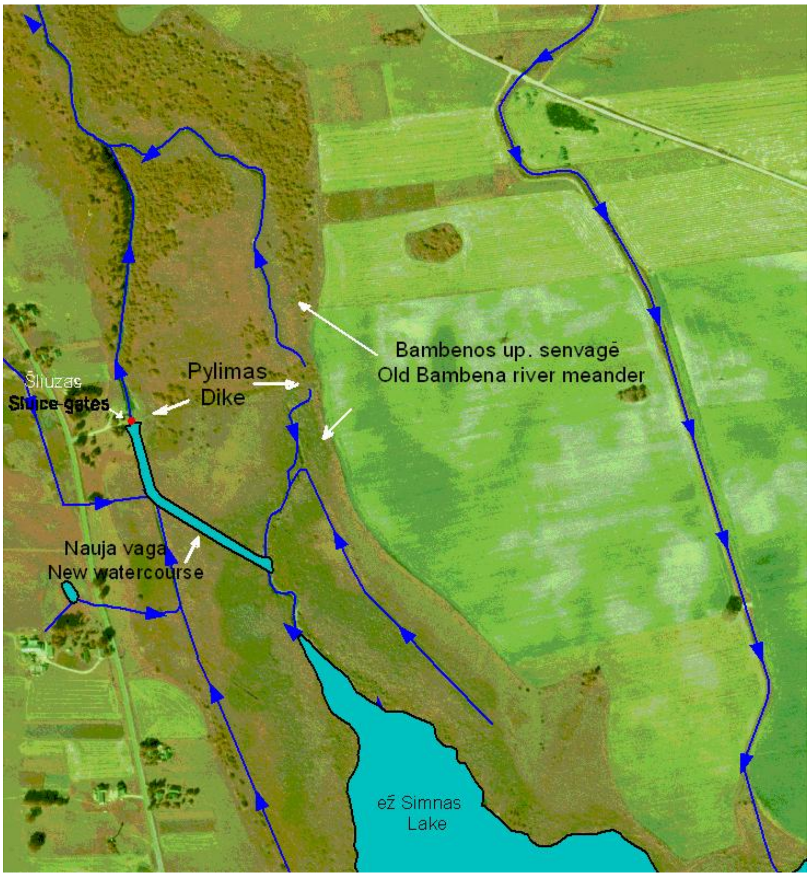

Fig. 4.5 The network of watercourses downstream Simnas Lake

When making artificial watercourse, a new arm of the river and a small dike (which separated the old meander) at a distance of 300 m from Simnas Lake were formed. At a distance of 280 m from that place the old meander was blocked by the other dike (crest altitude 93.00 m) in parallel with the axis (in its eastern size) of the sluice. Therefore, the reconstruction has split the old meander into two strips (280 and 580 m accordingly). However, many elements characteristic to natural streams (such as meandering, pools and shoals) still exists in the meander. These elements could do a favour aiming to reduce the flux of biogenic substances (especially phosphorus) from Simnas Lake as well as to restore the uncontrolled outflow.

While analyzing possibilities to reinstate the outflow from Simnas Lake through the old Bambena River meander similar simulation procedure as in scenario "1" was used. The basic feature of this numerical experiment was that according to the longitudinal profile and cross-sections of the old Bambena River meander, which were defined before the construction of the sluice-gate downstream Simnas Lake, outflow conditions and the change of water levels in the lake were "restored". Short-term data on water level fluctuations in Simnas Lake measured for the period from June 1960 to April 1961 (PSPI, 1961) was used to calibrate the model.

With the help of simulation the longitudinal profile and cross-sections of the Bambena River which existed before the arrangement of the sluice gates were "restored". According to the report based on hydrometric measurements (PSPI, 1961) the Bambena River bed downstream Simnas Lake before it was blocked by the dike had reverse (upward) slope. The bed bottom altitudes varied from 89.79 (near the lake) up to 90.25 m (at the site where the dike was built). Riverbed cross-sections changed marginally with the changing bottom and top width from 3.0 and 4.0 m up to 5.5 and 8.0 m, respectively. Cross-sections were close to the shape of parabola. At the site of the meander's partition (in parallel with the arranged sluice) the average bed bottom altitude was 90.23 m, the water depth in the cross-section fluctuated from 0.30 up to 1.65 m, and the width – from 3.0 up to 6.0 m. During the flood period the water overflowed from the watercourse into the nearby floodplain of 300 m in width. Downstream of this place the slope of the Bambena riverbed was gradually downward in the direction of Zuvintas Lake. Therefore, in the place where the dike is built the earlier natural riverbed cross-section conditioned the outflow from Simnas Lake as well as water levels' dynamics in the lake.

The simulation of outflow through the old Bambena River meander was carried out after the acceptance of the earlier-mentioned cross-section conditions, however, by evaluating the present situation as well. This means that the identical "old" cross-section was seemingly shaped in its primary place within the present dike. The dike was "dug through". The operating sluice gates were "replaced" by the dike the top (crest) altitude of which was 92.00 m. It corresponds to the upper crest altitude of the present sluice gates. Therefore, the water outflow from the lake occurred only through the old Bambena River meander. The inflow to Simnas Lake was conditioned by the outflow from the regulated Dusia Lake and Kalesninkai pond.

Such scenario enabled to combine referential (by taking into account riverbed cross-section before the arrangement of sluice gates) and present (by taking into account changed environment in terms of inflow) conditions in order to evaluate the possibilities to restore the outflow from Simnas Lake more realistically.

The simulation results have shown that after the restoration of the outflow through the old Bambena River meander, water levels in Simnas Lake would lower significantly (Fig. 4.6). The difference of the average water levels reaches 0.77 m when analysing the scenarios of "regulated" and "unregulated" water regime in the lake.

However, in the case of "natural" outflow water level fluctuations in Simnas Lake would increase by more than threefold. The highest fluctuation amplitude can reach 1.67 m. In the case of regulated lake – 0.37 m only. The coefficient of variation for the case of natural outflow would increase up to C_v=0.0028 (in case of regulated lake – only 0.00091). During flood periods water levels in the lake would mostly fluctuate in between the altitudes of 91.40 and 91.75 m. The average water level in the lake would be above the mark of 91.12 m (in the case of regulated lake - 91.99 m). The maximum water level can reach 92.19 m, and the minimum one – 90.52 m. Such fluctuations would assume features characteristic to natural lakes.

According to the outflow restoration scenario the average daily discharges at the outlet from Simnas Lake would not differ significantly from the regulated ones (Fig. 4.7). However, during dry periods the outflow would be almost twice higher and in wet periods – on the average by 25% smaller.

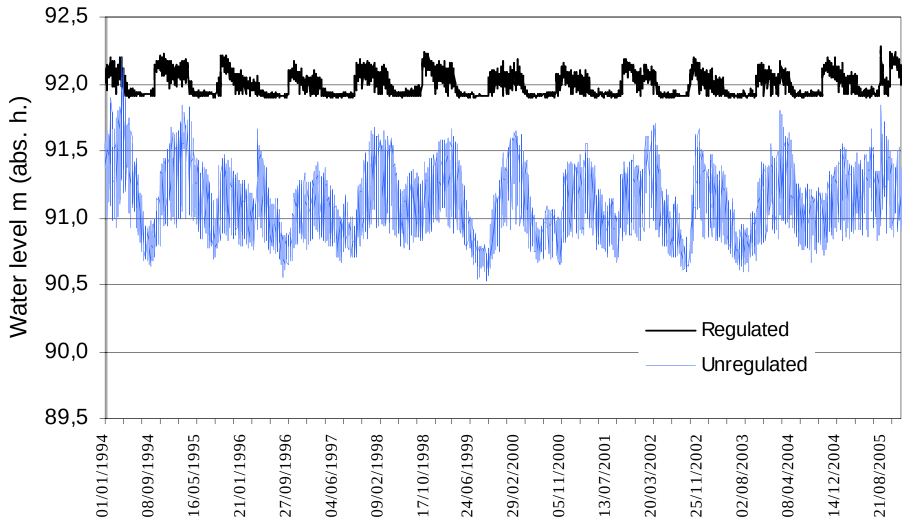

Fig. 4.6 Water level in Simnas Lake under regulated and unregulated outflow scenarios

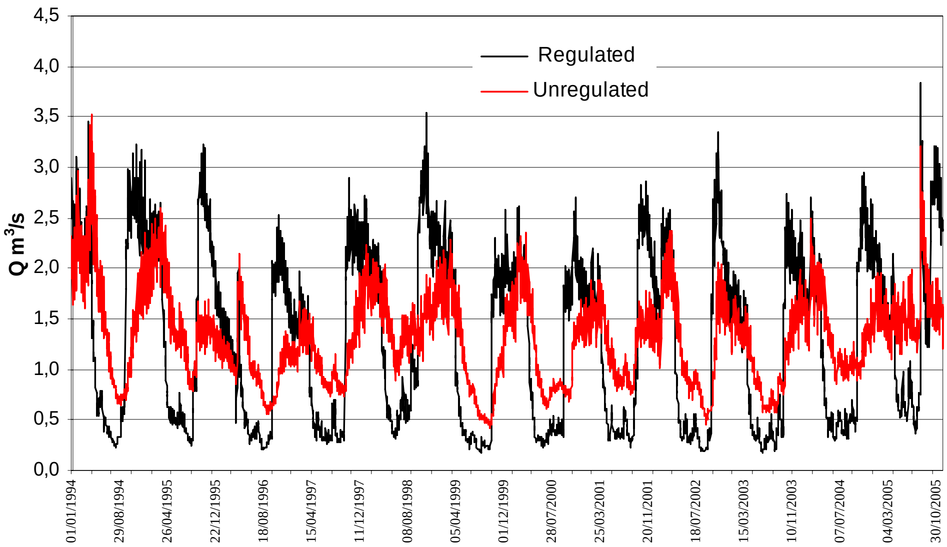

Fig. 4.7 Outflow discharges from Simnas Lake under regulated and unregulated conditions

The changes in surface water dynamics would condition the changes of groundwater level in surrounding areas as well. The differences between the groundwater levels around Simnas Lake under "regulated" and "restored outflow" conditions are shown in Figs. 4.8 and 4.9. The minus sign in the figures shows the magnitude of the decrease of groundwater level compare to scenario "0".

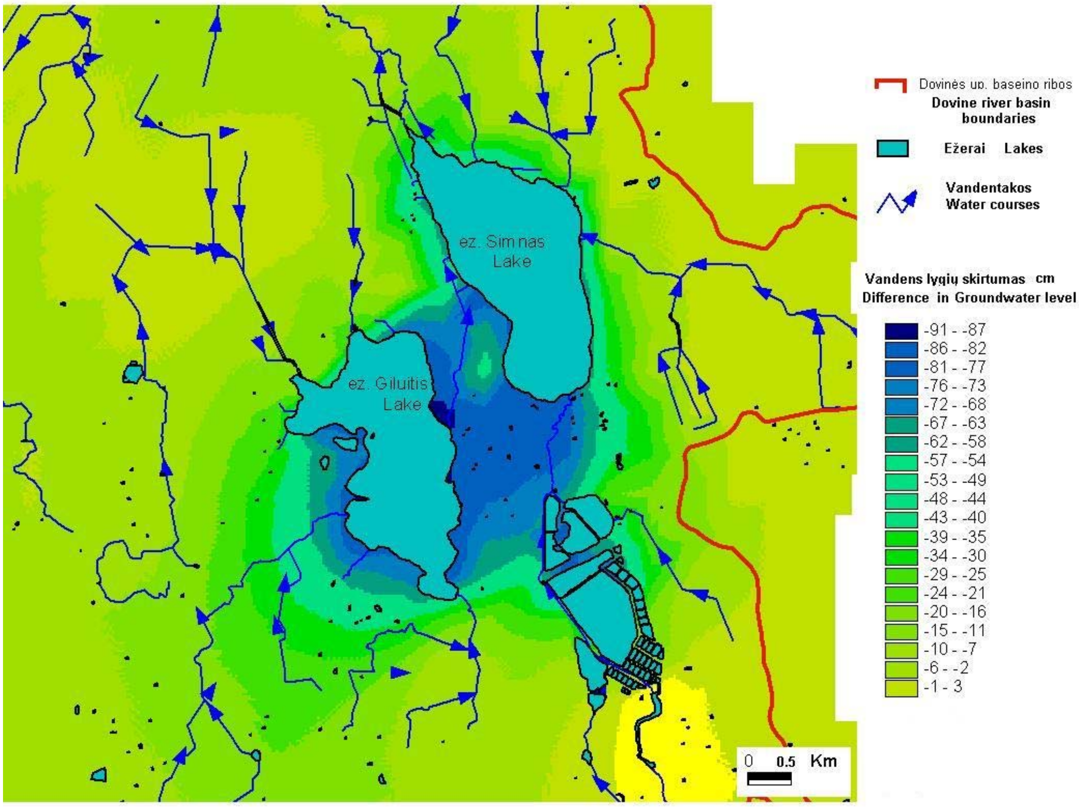

Fig. 4.8 Difference in average highest groundwater levels around Simnas Lake in winter (comparison between "regulated" and "restored" outflow scenarios)

During wet periods the groundwater level most of all would decline in the areas situated to the south-west from Simnas Lake (in the territory as far as Giluitis Lake). There the difference of water levels (in comparison with the present situation) would make on the average 60-80 cm (Fig. 4.8). In the eastern part of the shores of Simnas Lake groundwater levels would decline by 15-30 cm. Such decline would have impact on the areas situated at a distance of 300 m from the lake. In the south-eastern part of the lake's shores water levels can decline by 40-50 cm. Such change of groundwater levels would be perceptible in the territories of Simnas town itself and Simnas Fishery Enterprise (FE).

During dry periods the groundwater level can decline the most (from 80 to 100 cm) in the area between Simnas and Giluitis Lakes (Fig. 4.9). In the eastern shores of Simnas Lake the changes can encompass the territory of up to 500 m where the groundwater levels could decline from 20 up to 70 cm. In the southern part of the lake's shores (in comparison with the present situation) the groundwater level would decline by 70-100 cm. It would have a significant impact on the pond complex of Simnas FE. The water level decline in the areas situated to the north from Simnas Lake would reach up to 50 cm and such impact would be perceptible at a distance of approx 500 m.

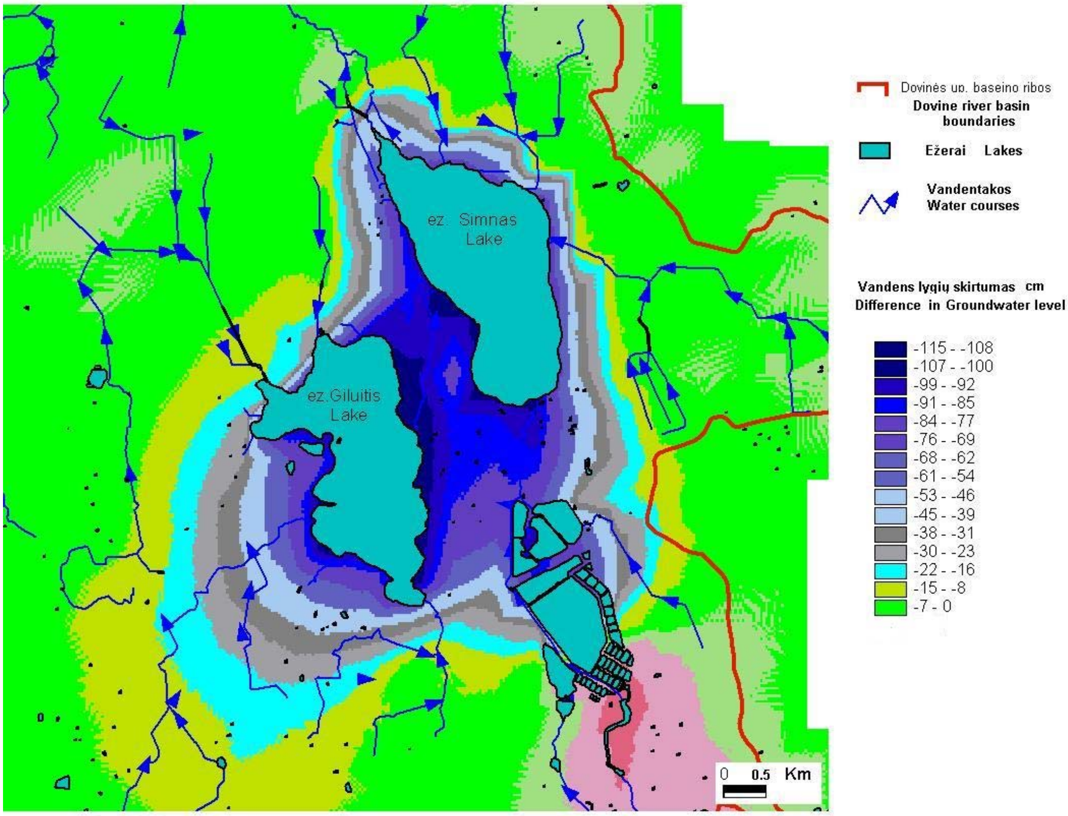

Fig. 4.9 Difference in average lowest groundwater levels around Simnas Lake in summer (comparison between "regulated" and "restored" outflow scenarios)

It makes clear from the presented results that restoration of the outflow from Simnas Lake through the old Bambena River meander would condition significant water level decline in Simnas Lake itself and the lowering of groundwater level in the surrounding areas. The changes of the groundwater level would have the highest impact on the territories in between Simnas and Giluitis Lakes as well as on the areas between Simnas Lake, Simnas town and Simnas Fishery Enterprise.

If such the dynamics of surface and/or ground water level in Simnas Lake and the surrounding territories (during dry period in particular) would not meet ecological or economic requirements, the cross-section of the restored outflow and the conditions of flow in the old Bambena River meander should be defined according to the demand.

4.4 Scrub encroachment in Amalvas and Zuvintas wetlands (scenario "3")

The complex of wetlands around Amalvas Lake covers the area of 1826 ha, the largest part of which is covered by raised bogs (1506 ha) situated in the territory of the Amalvas Botanic-Zoological Reserve on the both banks of the Dovine River (raised bogs that are drained at present). The edges of these raised bogs are overgrown with the thin strip of forest. According to prevalence of vegetation, the deciduous forest in Amalvas wetland covers 29%, coniferous forest - 11%, scrubs - 9%, mixed forest - 2%, open reed/sedge areas - 6%, open areas in sparse forest type - 43% (Fig. 4.10). The complex of Zuvintas Lake wetlands covers the area of 5790 ha. The raised bogs (including and of the transition type ones) make up more than 70% (4176 ha) of the entire territory. The sparse forest extended (it covers 31% of the territory) mostly into the north-eastern part of the raised bogs of Zuvintas Lake between the Bukta forest, the Kiaulycia Botanic-Zoological Reserve and the outflow of Zuvintas Lake. The areas of sparse forest are surrounded by dense coniferous forests. They cover the largest part of the northern raised bog of Zuvintas. The total area of coniferous forest reaches 33% of the Zuvintas wetlands' area. Deciduous forests (except the Bukta forest) make up 14%, scrubs - 2%, open fens - 20% (Fig. 4.11).

Fig. 4.10 Sparse deciduous forest in Amalvas raised bog

Table 4.2 Scenarios of the removal of scrubs and trees in the complex of Zuvintas and Amalvas wetlands

Wetland	Scenario	The removed area of scrubs and trees (%)	The area of scrubs and trees (%)	Open area (%)
Zuvintas	"0"	-	80	20
	"R1"	16	64	36
	"R2"	49	31	69
	"R3"	80	0	100
Amalvas	"0"	-	94	6
	"R1"	21	73	27
	"R2"	51	43	57
	"R3"	94	0	100

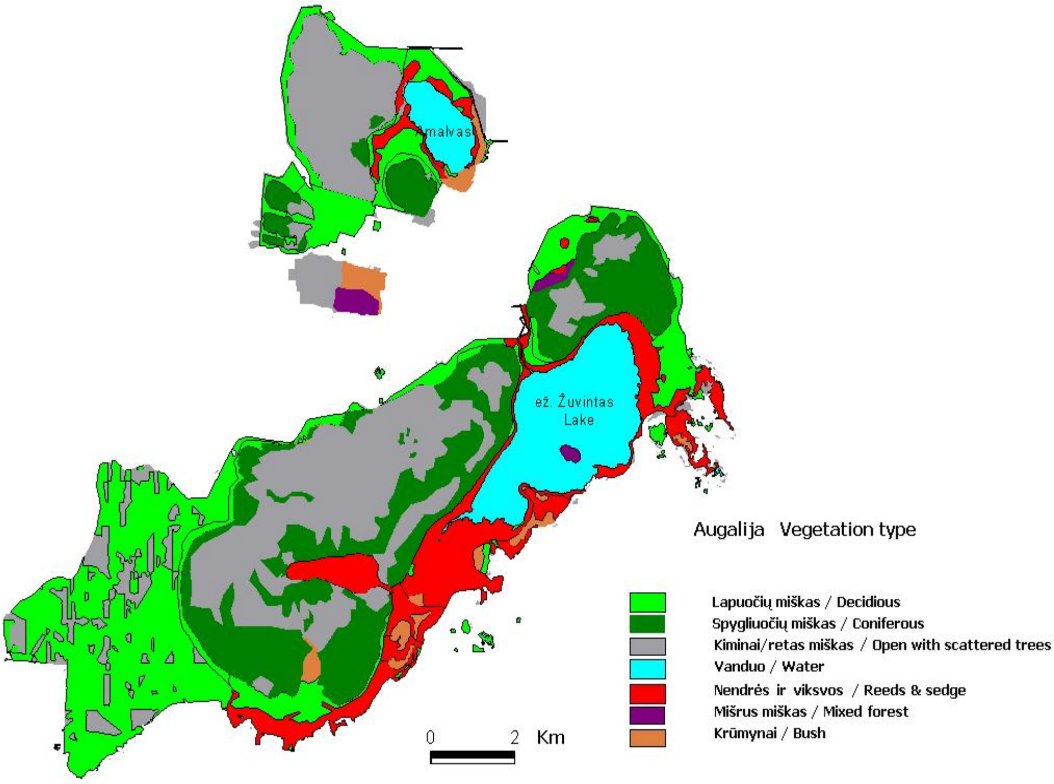

Fig. 4.11 Vegetation of Zuvintas and Amalvas wetlands

The change of vegetation can significantly change the water balance in raised bogs, when the prevailing grassy peat-moss cover is invaded by scrubs and trees. Trees evaporate (transpiration) more water with the help of their top crowns. Due to this reason the total evapotranspiration increases as well. The stronger evaporation conditions the decline of groundwater level. Consequently, mineralization of organic matter intensifies in drained layer. Natural vegetation in wetlands is vanishing.

Mathematical simulation is a useful tool because it allows investigation of any process by changing its parameters without distortion of physical meaning of the process. With the help of the simulation it is easy to analyse the impact of the changeable parameters upon the researched object. The possible influence of the changed vegetation cover in Zuvintas and Amalvas wetlands upon the groundwater levels in them was evaluated according to this principle. The attributive parameters of the GIS-based land use layer in SIMGRO model were changed in such way that grassy peat-moss (*Oxycocco Sphagnetea*), reed and/or grass (sedge) vegetation characteristics typical to raised bogs or fenns were chosen instead of coniferous and deciduous forests and shrub areas. The following three options/scenarios (Table 4.2) were analysed: 1) when the areas of deciduous forest and scrubs situated on the edges of fens (not taking into account drained Amalvas raised bogs) are removed (scenario R1); 2) when the complexes of conifers and mixed forests growing in raised bogs (including the areas of deciduous forest in drained Amalvas raised bogs) are removed (scenario R2) and when 3) sparse forest is turned into open areas (scenario R3). The second option was the sequence of the first one, which evaluated its outcomes. The third option reflects all outcomes of the removal of scrubs and trees in the complex of Zuvintas and Amalvas wetlands. Later, the results of all options were compared to those of the present conditions (scenario "0").

The structure of the SIMGRO model is made in such way as every land use type corresponds to the different plant physiological conditions (leaf area index, precipitation interception, root depth) and other parameters (duration of vegetation period and etc.) corresponding to them. Such change conditions the change of water balance in the soil. Analyzing the difference between the present and the changed conditions, possible impact tendencies in time and space have shown up.

After the reduction of the areas of coniferous forests and scrubs according to the scenario R1, the area of the open space would increase by 16% in the complex of Zuvintas wetland, and 21% around Amalvas wetland. Such change during the summer would result in "the rising" of the water level from 1 to 120 cm, when comparing with the scenario "0". The most vivid it would be in the northern and eastern outskirts of Zuvintas wetland and in the south-western part of the Kiaulycia Botanic-Zoological Reserve (Fig. 4.12). The removal of the deciduous forest in the wetland complex edges around Amalvas Lake would "raise" the groundwater level mainly in the northern part of the Amalvas Botanic-Zoological Reserve and in the left bank of the Amalve River (the south-western bank of Amalvas Lake).

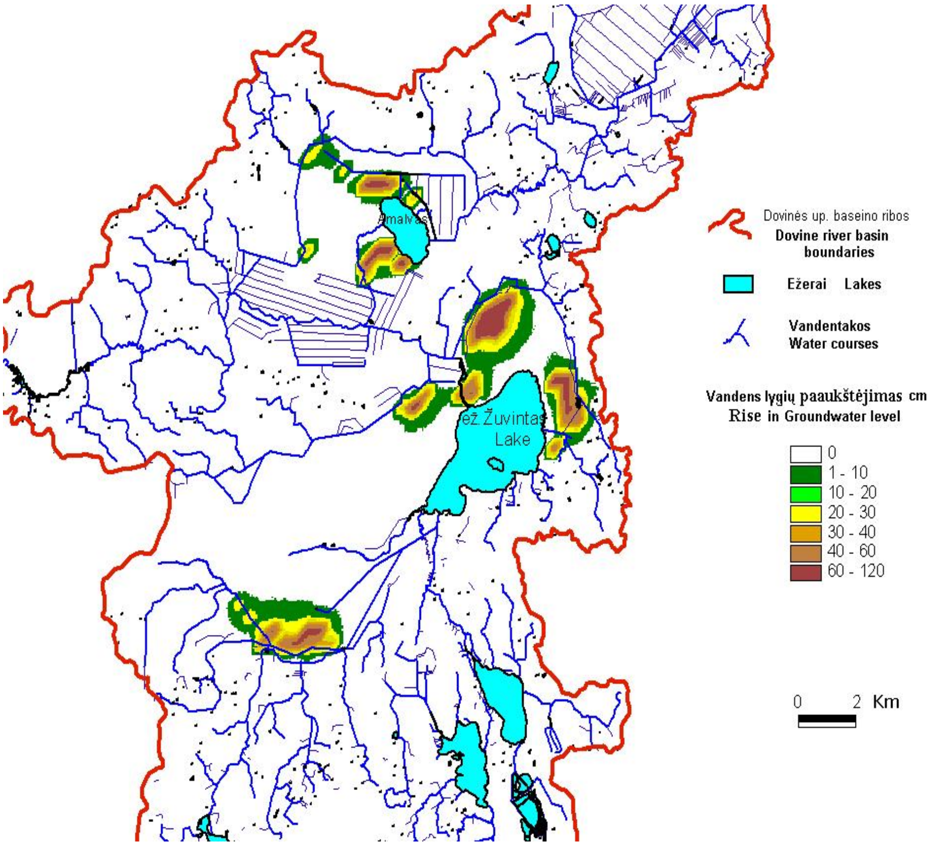

Fig. 4.12 The impact of the removal of deciduous trees and scrubs upon the groundwater level changes in Zuvintas and Amalvas wetlands in dry season in comparison with the scenario "O"

When comparing water level changes in winter time with the scenario "0", the tendencies of the spatial distribution would remain similar to those of the summer (Fig. 4.13). On the other hand, these changes would encompass the larger territory and water level "risings" wouldn't be as vivid – 17 cm on average. Maximum changes would reach 60 cm. Vegetation of deciduous trees due to higher transpiration rates conditions more significant changes going on in summer.

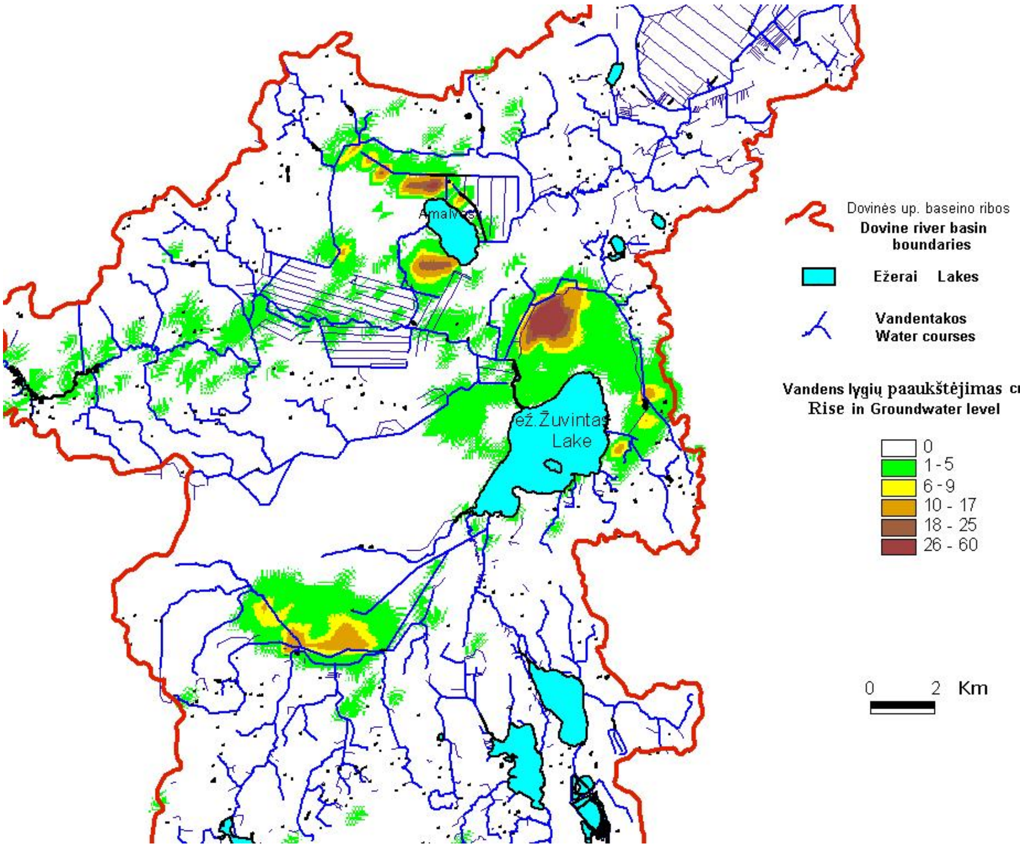

Fig. 4.13 The impact of the removal of deciduous trees and scrubs upon the groundwater level changes in Zuvintas and Amalvas wetlands during winter in comparison with the scenario "0"

After additional reduction of the area overgrown with the forest in the complex of Zuvintas wetlands by 33%, and in Amalvas wetlands – by 30%, the total area of the removed scrubs and trees would make up 49% and 51% of the whole territory, respectively. Such activity would correspond to the simulation scenario R2. Following this scenario coniferous woodland and mixed groves should be cut down in the raised bogs. It means that open area in the complex of Zuvintas and Amalvas wetlands would increase by 2.5 and 8 times, respectively. The open space in the wetlands around Zuvintas Lake would cover 69%, and around Amalvas Lake - 57% of the entire territory. The remaining part would stay overgrown with sparse forest.

After the implementation of this scenario the groundwater level would rise significantly. During summer season the "rise" of the groundwater level in different places would reach from 10 to 160 cm when comparing with the option "0". Mostly, it would rise in the central part of Zuvintas raised bog and in the northern wetlands of Zuvintas Lake (Fig. 4.14), where a dense coniferous woodland is situated. The largest changes in the wetlands around Amalvas Lake would be observed in the drained raised-bog (on the right bank of the Dovine River) and in the territory between the southern strand of Amalvas Lake and the sluice-gate. There, the groundwater level would rise by 20-90 cm.

During winter the water level would rise from 10 to 90 cm (Fig. 4.15). In the large part of the raised bogs the rise would reach from 4 to 30 cm. The places of the highest water level "rise" coincide with the places of coniferous wood growth.

From the presented analysis one can see that forest vegetation significantly lowers groundwater levels in the raised bogs. Mostly, these differences clear up during summer draught periods (in June-August). For the accentuation of the above-mentioned consistent patterns the analysis of the water level change at different places of the wetlands was carried out (Fig. 4.16).

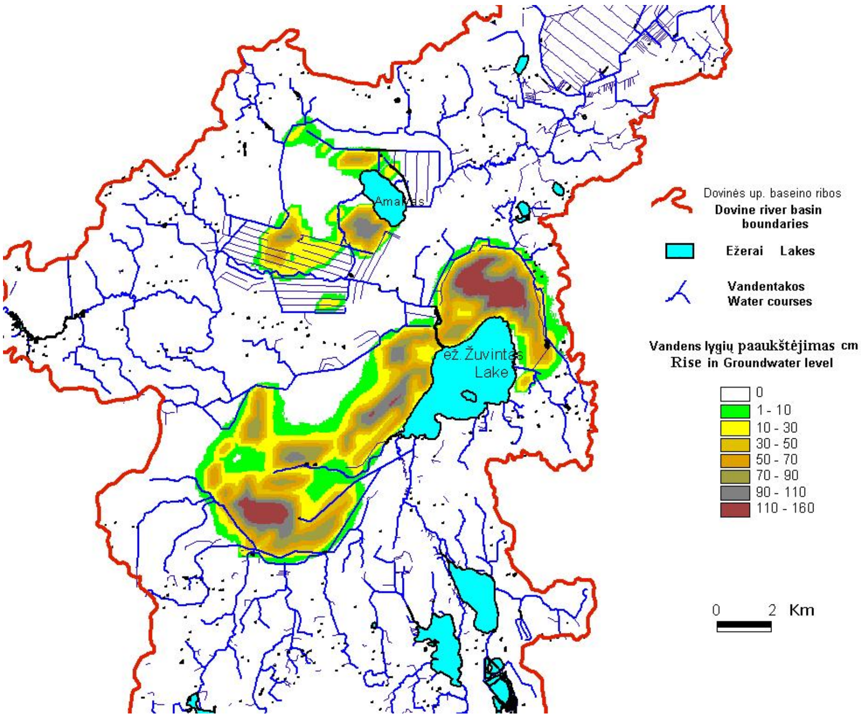

Fig. 4.14 The impact of the removal of the areas of deciduous, coniferous and mixed forests upon the groundwater level changes in Zuvintas and Amalvas wetlands during dry season in comparison with the scenario "0"

The groundwater level dynamics at two points of Zuvintas and Amalvas wetlands (in simulation nodes following the SIMGRO model schematization) is shown in Figs. 4.17-4.18. Nodal point 1974 shows groundwater level conditions in Zuvintas wetland, and at the node 1163 characterises the intermediate stage between Amalvas raised bog and fen (Fig. 4.16). The nodal point in Zuvintas raised bog reflects conditions with the covering of coniferous woodland and the point in Amalvas wetland – with the covering of deciduous trees.

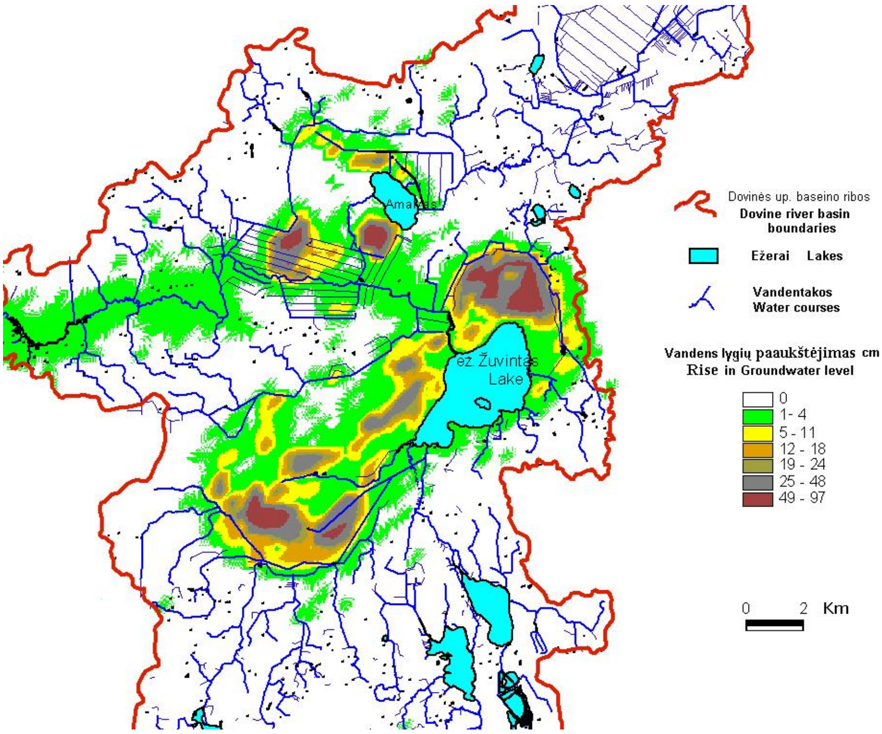

Fig. 4.15 The impact of the removal of the areas of deciduous, coniferous and mixed forests upon the groundwater level changes in Zuvintas and Amalvas wetlands during winter in comparison with the scenario "0"

The impact of the removal of deciduous trees in nodal point 1163 of Amalvas transitional mire manifests in the rise of groundwater level by 55 cm on average (Fig. 4.17). During dry season the difference between the rise of groundwater level with woodland and without it can reach up to 65 cm. During wet periods it decreases up to 17-30 cm.

In Zuvintas raised bog (node 1974) the impact of the removal of coniferous forest manifests in the rise of groundwater level by 70 cm on average, in comparison with the scenario "O" (Fig. 4.18). During dry periods this impact can reach 90 cm.

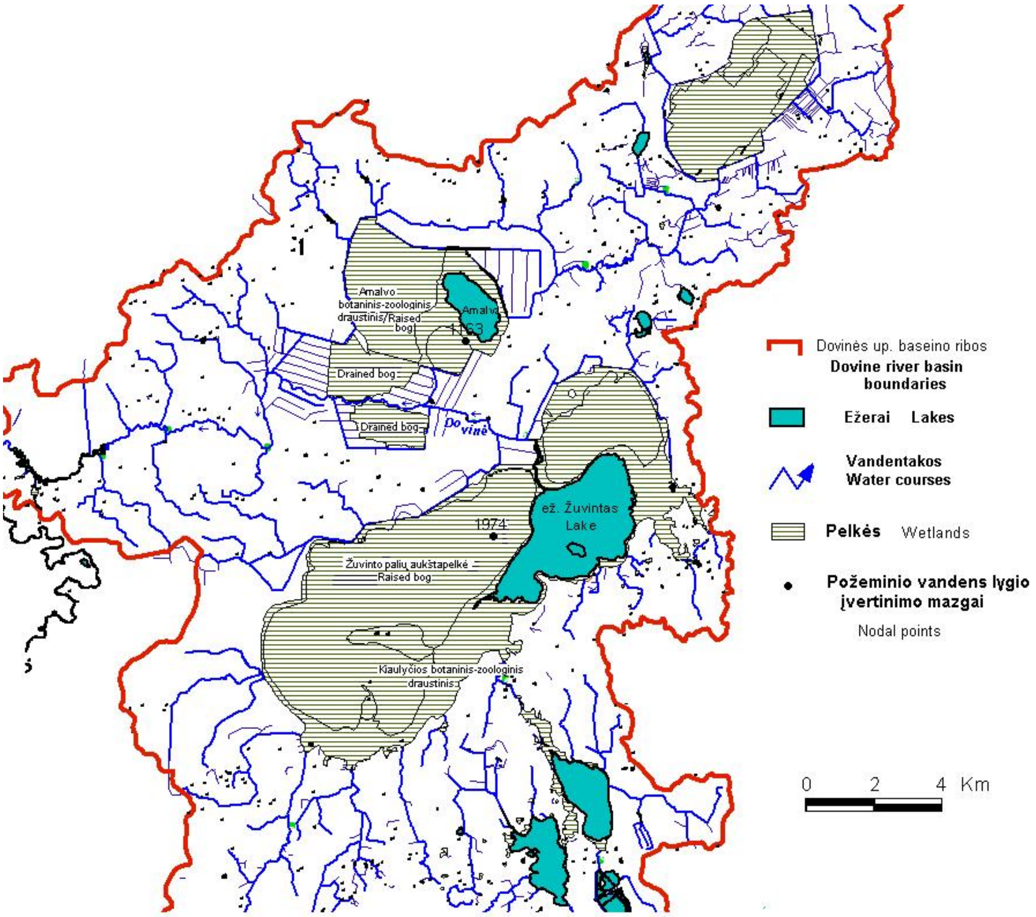

Fig. 4.16 Sites of evaluation of groundwater level in Zuvintas and Amalvas wetlands

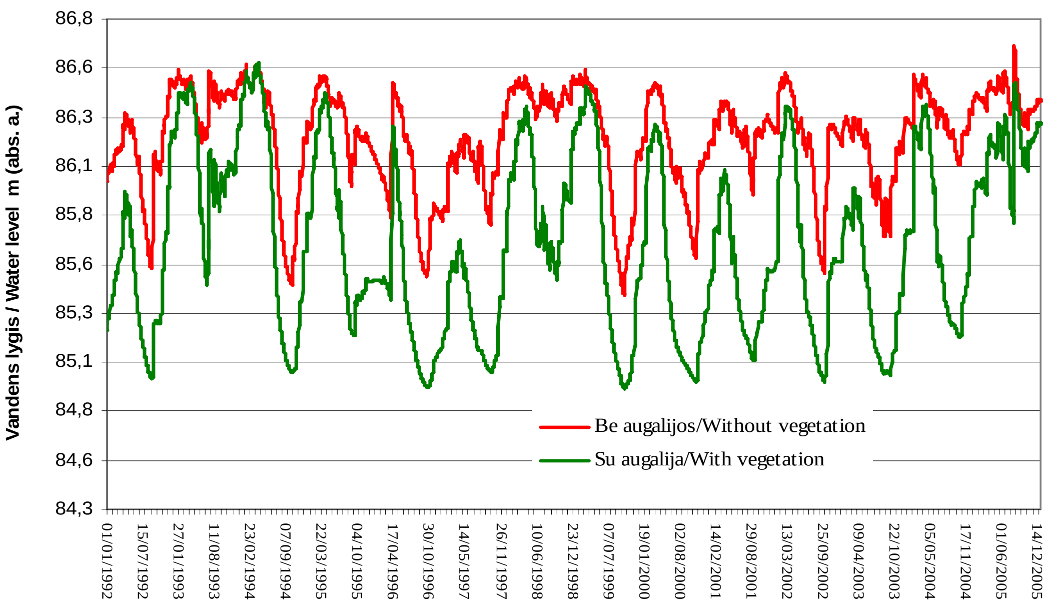

Fig. 4.17 The impact of vegetation upon the groundwater level dynamics in Amalvas wetlands (node 1163)

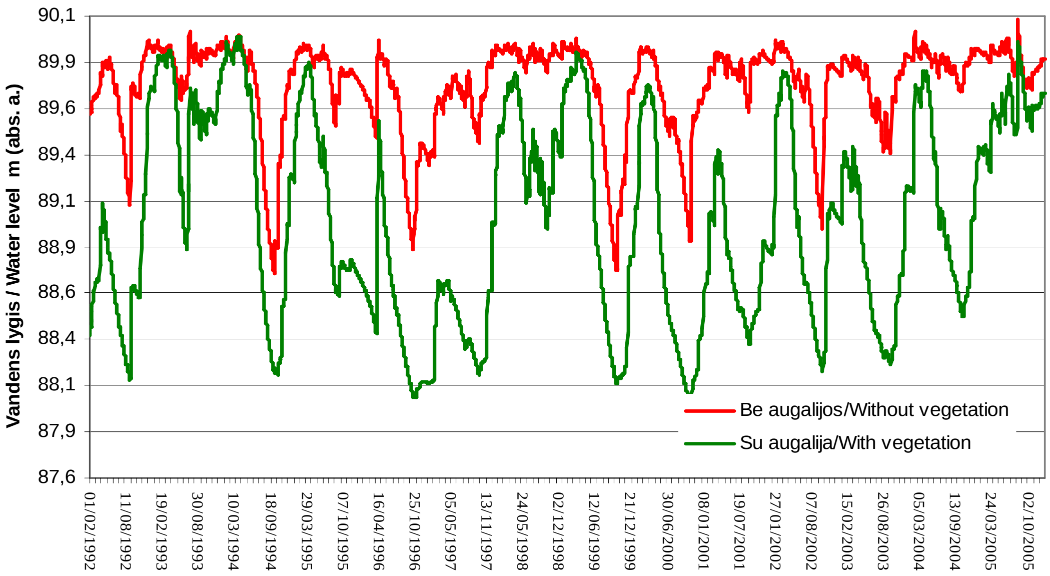

Fig. 4.18 The impact of vegetation upon the groundwater level dynamics in Zuvintas raised bogs (node 1974)

While analysing the impact of vegetation following scenario R3 a situation clears out when the entire area of scrubs and trees in the complex of Zuvintas and Amalvas wetlands would be removed. It means that in parallel with the above-discussed removal of coniferous and deciduous forests and scrubs the trees in the areas of the sparse forest would be removed as well. These areas in Zuvintas and Amalvas wetlands cover 31% and 43% of the total area, respectively. In such case the entire complex of wetlands would turn into the open areas with the prevailing cover of grassy peat-moss and reeds/sedges instead of at present prevailing forest cover.

The results according to this scenario showed that the removal of the sparse forest wouldn't have significant influence upon the "rise" of groundwater levels. The more vivid water level risings in the sparse forest areas would be noticeable only during summer season (Fig. 4.19). The water level in Zuvintas raised bog would rise from 3 up to 14 cm, and in the territory of Amalvas Botanic-Zoological Reserve – from 3 up to 8 cm. There would be no change in other parts of the complex of wetlands. During winter the "rise" of the groundwater level is not expected as well due to the removal of sparse forest.

From the presented analysis one can see that coniferous and deciduous forests have the highest impact upon the groundwater level fluctuations in the complex of Zuvintas and Amalvas wetlands. Their highest impact is estimated during summer season. After the removal of the scrubs and trees, changes of water level (in comparison with the scenario "0") would be similar to the results of the scenario R2. In order to "raise" the groundwater level in Zuvintas and Amalvas wetlands it is recommended to remove the scrubs and trees. Such vegetation removal wouldn't have significant impact upon the water level dynamics in Zuvintas and Amalvas Lakes.

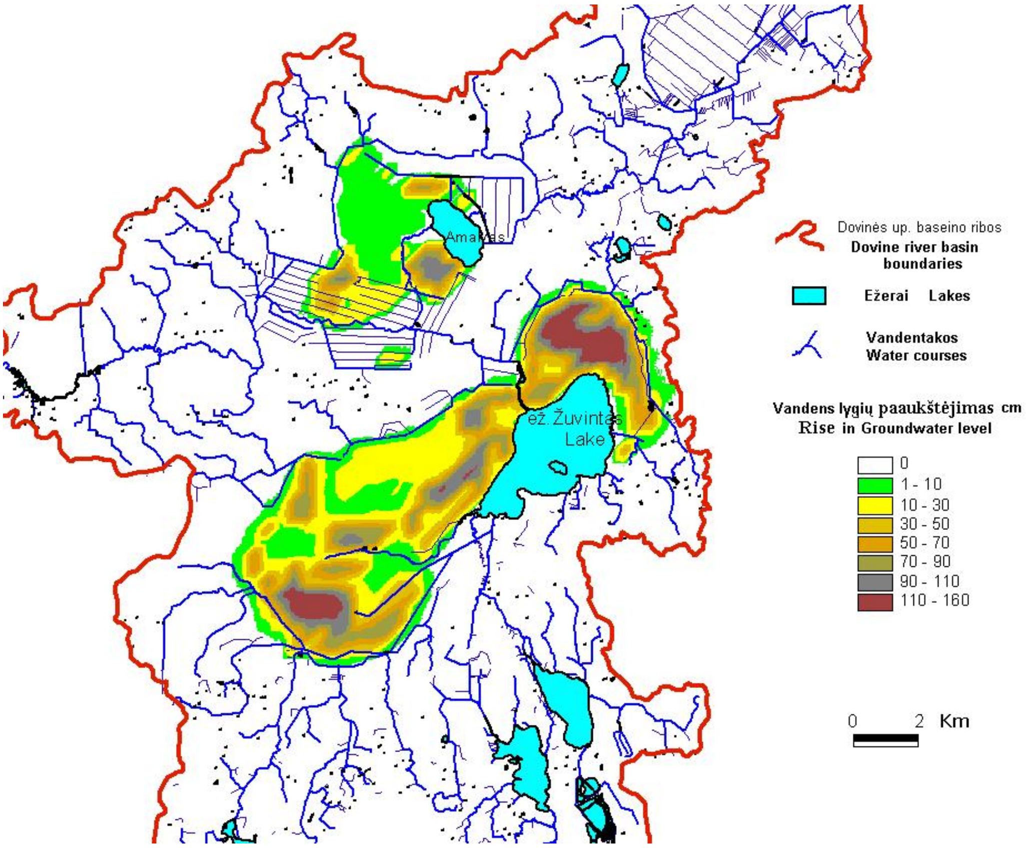

Fig. 4.19 The impact of the removal of all scrubs and trees upon groundwater level changes in Zuvintas and Amalvas wetlands in summer season in comparison with the scenario "0"

4.5 Blocking of drainage ditches around Zuvintas and Almalvas wetlands (scenario "4")

As it was already mentioned (see Chapter 1) during the eighth decade of the last century intense land reclamation works have been going on in the Dovine River Basin. In the territories surrounding Zuvintas and Amalvas Lakes ditches were dug and subsurface drainage was being arranged. The main objective of these measures was to lower groundwater level in the surrounding agricultural areas because of the raise in water level in the lakes. For this purpose, in the northern, north-western and north-eastern parts of the wetlands surrounding Zuvintas Lake drainage ditches were dug (areas within rectangles in Fig. 4.20). They had the protective (from the lateral inflow) and flow diversion functions. However, wetland areas adjacent to Amalvas Lake were those impacted by land reclamation activity at most. The dykes and polder system were arranged in the north-eastern part; a lot of 2.0 m and even deeper ditches were dug in the southern and south-eastern parts. Consequently, the groundwater level on the outskirts of wetlands has been lowered and surrounding areas have been used for agricultural purposes.

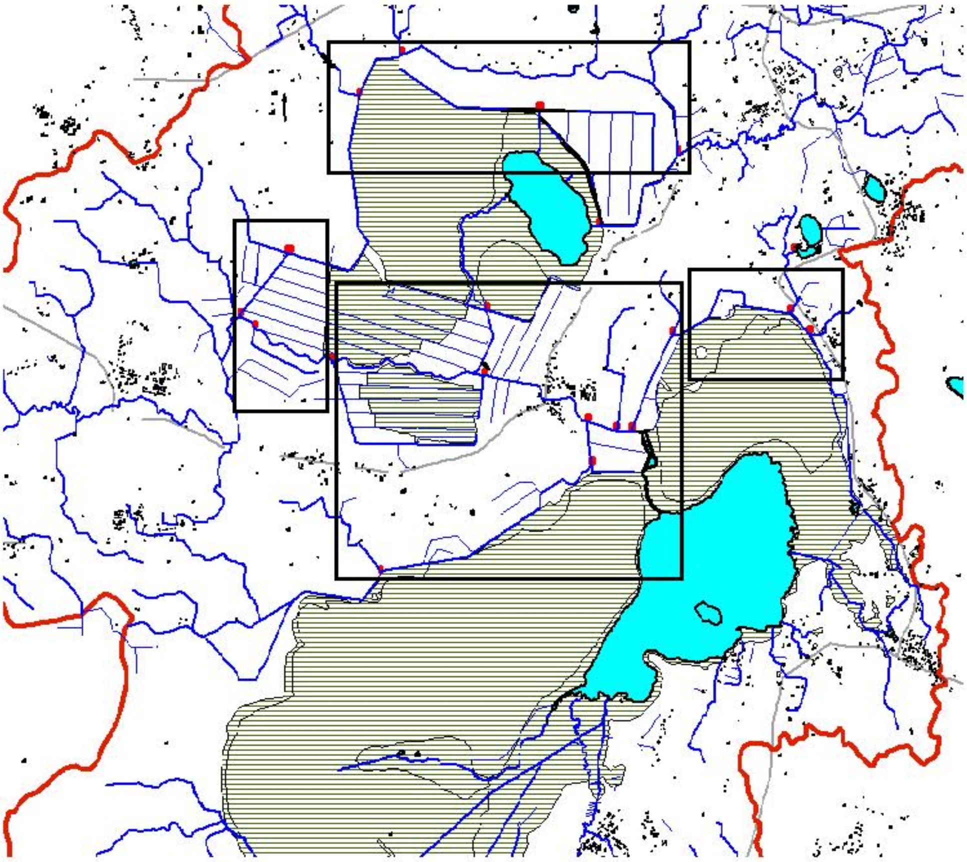

Fig. 4.20 The network of artificial watercourses (ditches) around Zuvintas and Amalvas Lakes

The rise of groundwater level at the outskirts of Zuvintas and Amalvas wetlands can be achieved by raising the water levels in the draining ditches by means of small dams or bars. It can be done by arranging blocking walls at a certain cross-sections (red dots in Figure 4.20). The height of the blocking walls would correspond to the water level in the ditches according to the 10% probability discharge. The damming is being planned only in such ditches, which are adjusted to the group of the eliminated-to-be ditches following the Zuvintas Biosphere Reserve management plan.

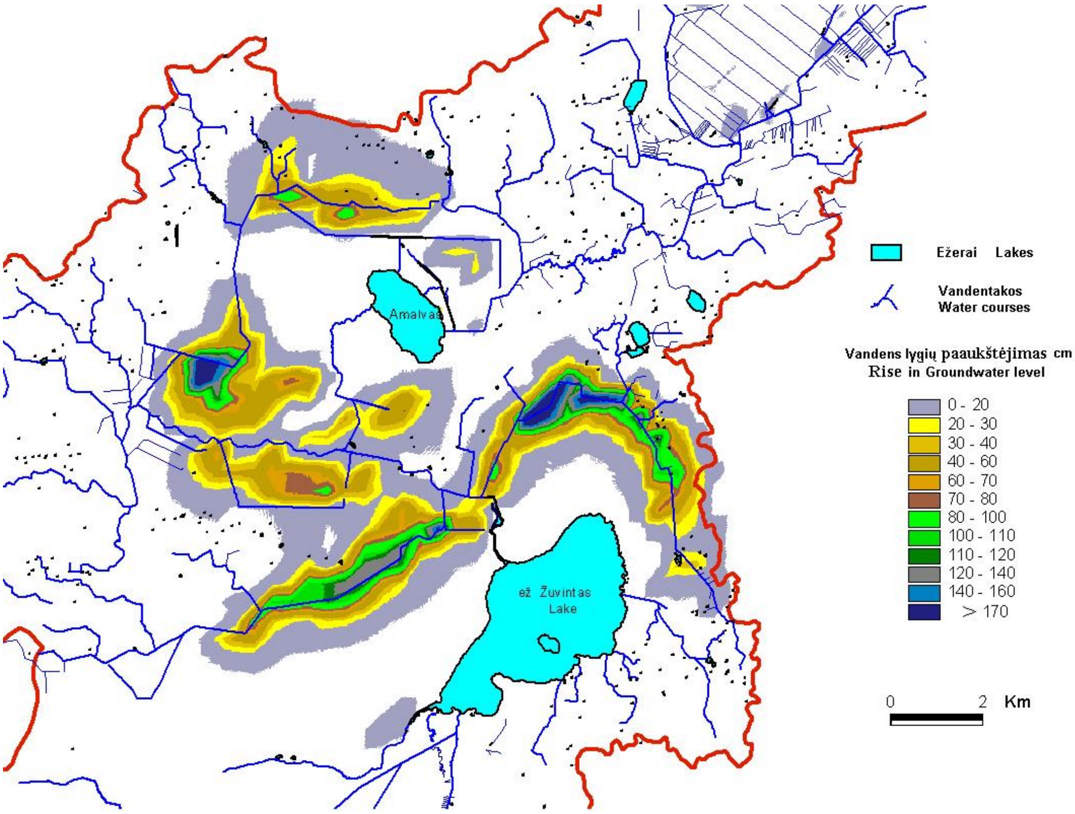

Fig. 4.21 Impact of the blocking of drainage ditches upon groundwater level changes around Zuvintas and Amalvas wetlands in summer season in comparison with the scenario "0"

The results from the simulation scenario revealed that on the northern, north-western and north-eastern outskirts of wetlands surrounding Zuvintas Lake the damming of water in the ditches would raise the groundwater level by 60-70 cm on average (Figs. 4.21-4.22). The maximum rise in groundwater level can reach more than 160 cm there. The cascade of small dams of various heights can affect the areas situated at a distance from 100 to 1000 m. The small dams in the ditches would affect the area of the drained Amalvas raised bog (to the south-west from the Amalvas Lake) in particular. There the groundwater level would rise by 60 cm on average.

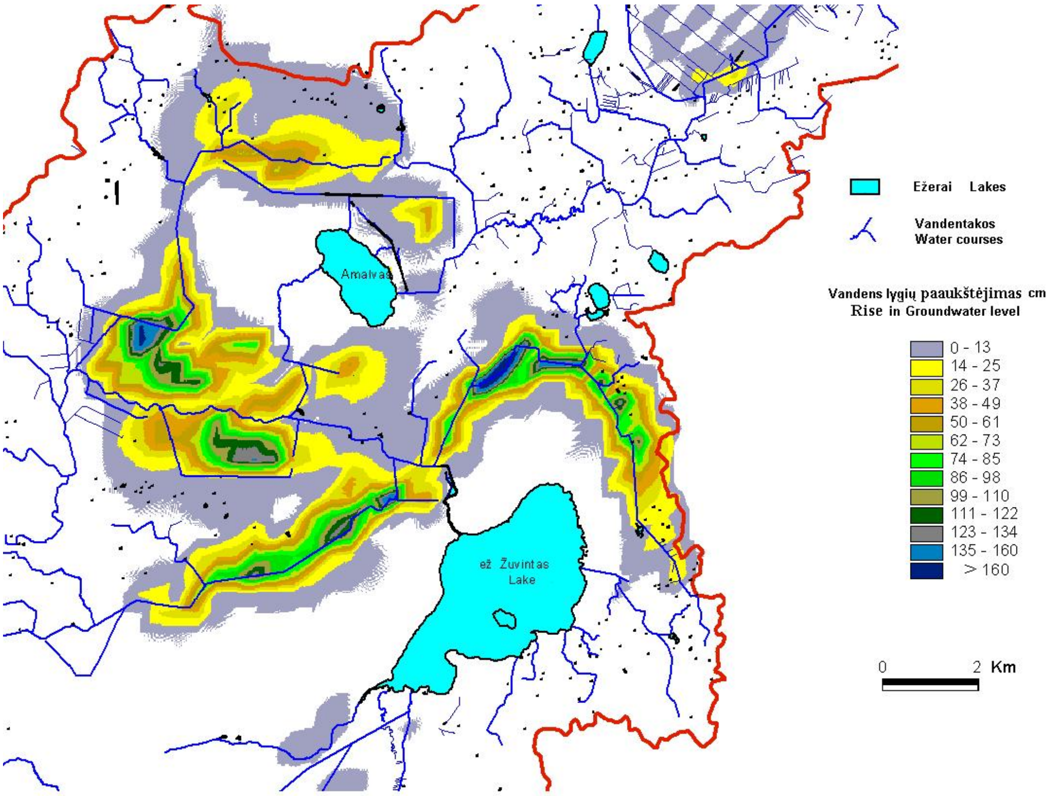

Fig. 4.22 Impact of the blocking of drainage ditches upon groundwater level changes around Zuvintas and Amalvas wetlands during winter in comparison with the scenario "0"

The small dams in the ditches on the outskirts of Zuvintas wetlands would have a positive impact on bird habitats however it would condition negative changes in the surrounding agricultural areas. Farming conditions would worsen, therefore, the implementation of this measure would be possible only after the buyout of private land from inhabitants or by making amends for the losses.

An alternative way is also possible when present ditches located on the outskirts of Zuvintas wetlands would be left for self-naturalization without obvious functions. Consequently, new ditches, dug at a distance of 100-200 m from the old ones would stimulate further draining functions of agricultural area and the conditions for agricultural activity would not worsen. However, it would be a very expensive measure, in addition, it would scar the landscape. For the implementation of this measure the buyout of private land from inhabitants and/or their acceptance for such activity might be inevitable.

4.6 Water regime restoration in Amalvas polder (scenario "5")

The Amalvas winter polder has been arranged in the north-eastern and northern outskirts of Amalvas wetland (Fig. 4.23). It is the former fen, where moisture excess was ensured by the high water level in Amalvas Lake and the Slavanta and Bebriute rivers. Throughout almost the whole year the fen used to be flooded with surface water. After having dug drainage ditches and after having arranged winter polder (total area 638 ha), meadows and pastures were arranged in this area.

The main channel (collecting water from lateral ditches) of the polder functions as reservoir as well (Fig. 4.24). Here the pumping station (consisting of two pumps) was built. Its' pumping capacity is 1.26 m^3/s. The water excess collected in the reservoir is transferred over the dike into another ditch with the help of pumps and runs off to Amalvas Lake. According to the pumping station's arrangement project, the water level in the main channel had to be automatically maintained between the 83.00 and 83.40 m altitudes. Consequently, the groundwater level in the Amalvas polder and in the north-western part of the Amalvas wetlands was declined more than by 2.0 m. Such significant water level lowering in the main channel was necessary for the maintenance of the effective functioning of subsurface drainage systems.

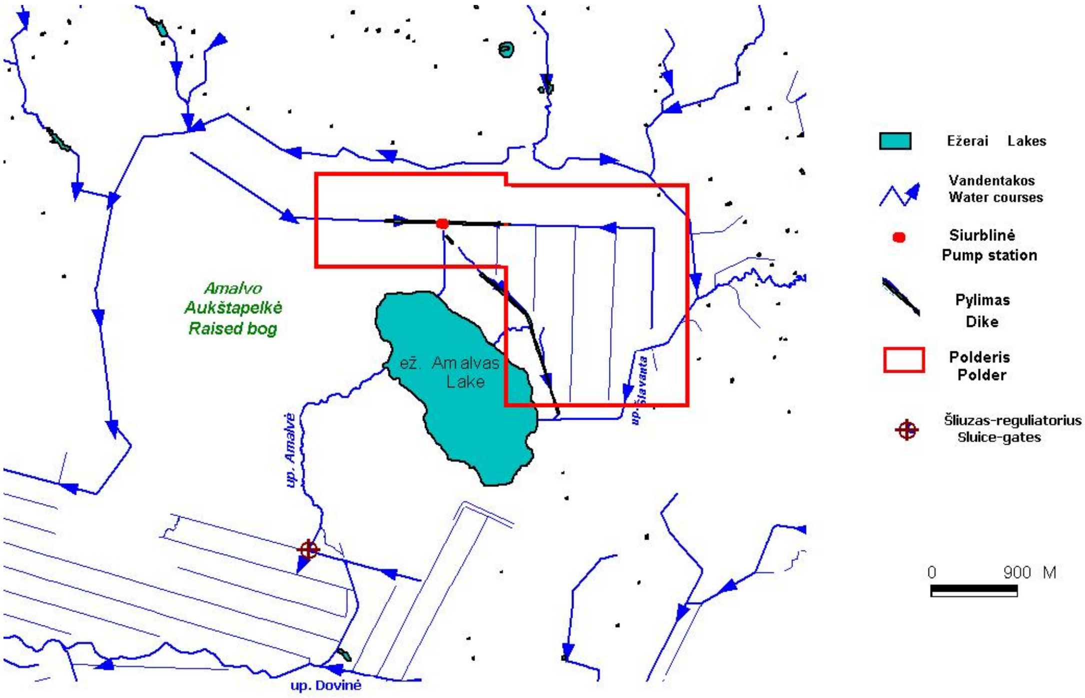

Fig. 4.23 Location of Amalvas winter polder

At present, there are no clear criteria for the operation of this pumping-station. It is handled manually, therefore, the pumps are turned on only when the water level in the main channel reaches the 84.5-85.0 m altitude. The equipment in this pumping station are broken down, they need to be renovated. Several sections of the main channel (in the northern outskirts of the Amalvas wetland in particular) are influenced by the processes of spontaneous self-naturalization. Cross-section deformations can be clearly seen there as well (Fig. 4.25).

Fig. 4.24 The main channel of Amalvas polder

Fig. 4.25 Self-naturalization processes in the main channel

When simulating water regime in Amalvas polder and its surrounding territories according to scenario "0" it emerged that the average highest groundwater level during wet period occurs at the depth from more than 2.0 to 0.20 m below the ground surface. The lowest water level (more than 2.0 m) is observed in the north-eastern part of the Amalvas polder as well as in the northern outskirts of the raised bog as well as in the area close to the pumping station (Fig. 4.23).

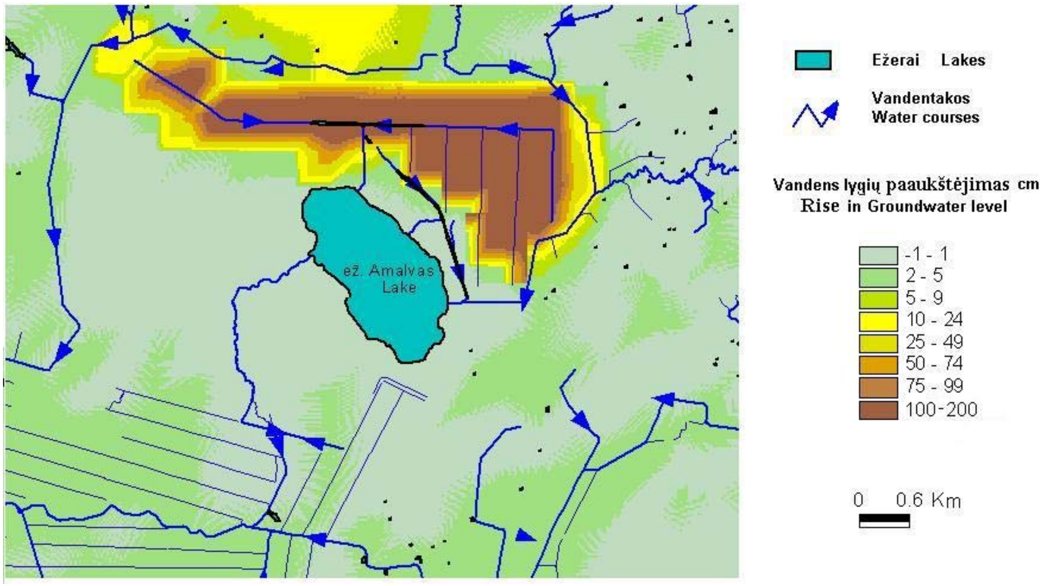

Fig. 4.24 The average raise of groundwater level in Amalvas polder during winter time in comparison with scenario "0" (the case of the shutdown of pumping station)

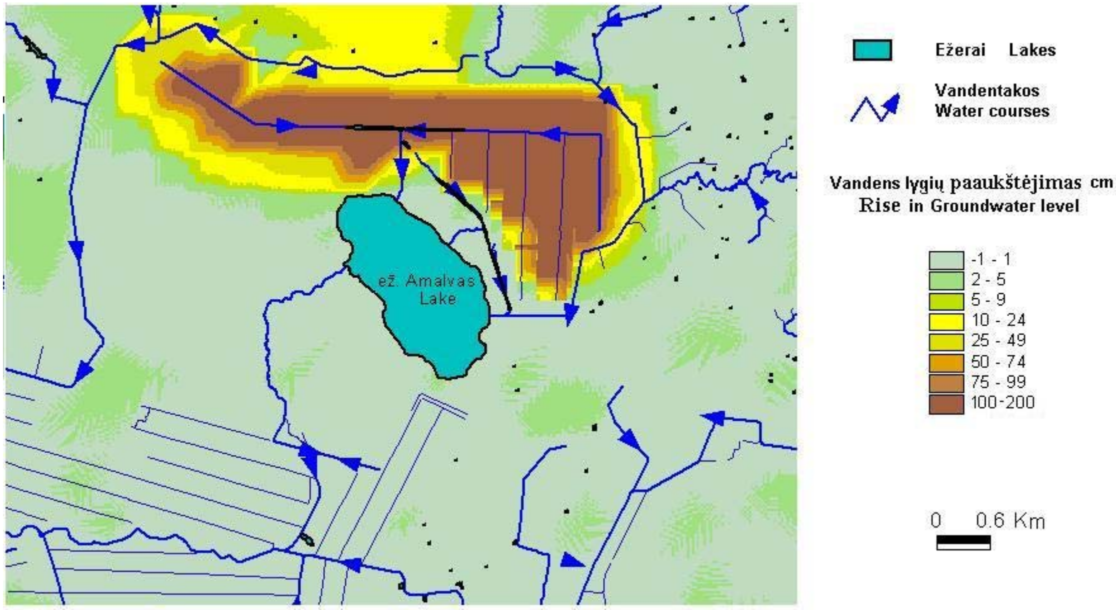

Fig. 4.25 The average raise of groundwater level in Amalvas polder during summer season in comparison with scenario "0" (the case of the shutdown of pumping station)

In spite of desultory functioning of the pumping station it remains an important tool for water level control in the polder. With the shutdown of this pumping station the water level in Amalvas polder and the surrounding areas would rise significantly. These alterations are well reflected by the simulation scenario on which basis the following situation is being imitated: *if the water "downthrow" from the Amalvas polder into the lake wouldn't be fulfilled.* Consequently, the northern part of the lake's catchment would be completely delimited from the lake. There wouldn't be any connection with the lake. Therefore, non-runoff area would start to develop in the polder. According to this scenario groundwater level during summer and winter (Figs. 4.24-4.25) can rise from 1.0 up to 2.0 m in the large area of the polder (in comparison with scenario "0"). Throughout the whole year the northern and south-northern parts of the polder would be waterlogged. Such measure would condition significant rise in the groundwater levels (>1.0 m) in the northern outskirts of the Amalvas wetland as well as in surrounding agricultural areas (up to 30 cm) between the settlement of Sventaragis and the villages of Pauziskiai and Bieliuniskiai.

After demolition of the pumping station and consequently *after the restoration of direct connection in between Amalvas Lake and the area situated in the polder*, the water regime in it would be directly influenced by water level fluctuations in the lake. Through the channel connecting Amalvas Lake and the pumping station the lake's water would overflow into the polder's main channel and ditches. Part of the inflow into Amalvas Lake from the catchment is expected to be accumulated in these ditches, therefore only seasonal polder's inundation in spring is presumable. Nevertheless, high water level (close to the ground surface) can persist in summer time.

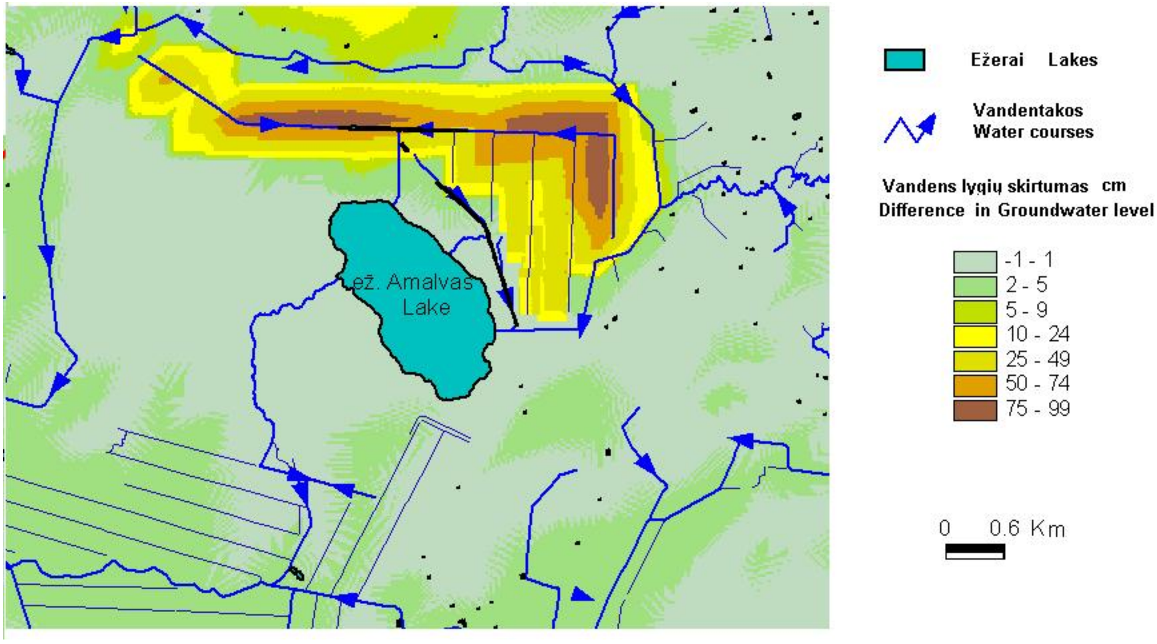

Fig. 4.26 The average rise of groundwater level in Amalvas polder during winter after the restoration of connection with the lake (in comparison with scenario "0")

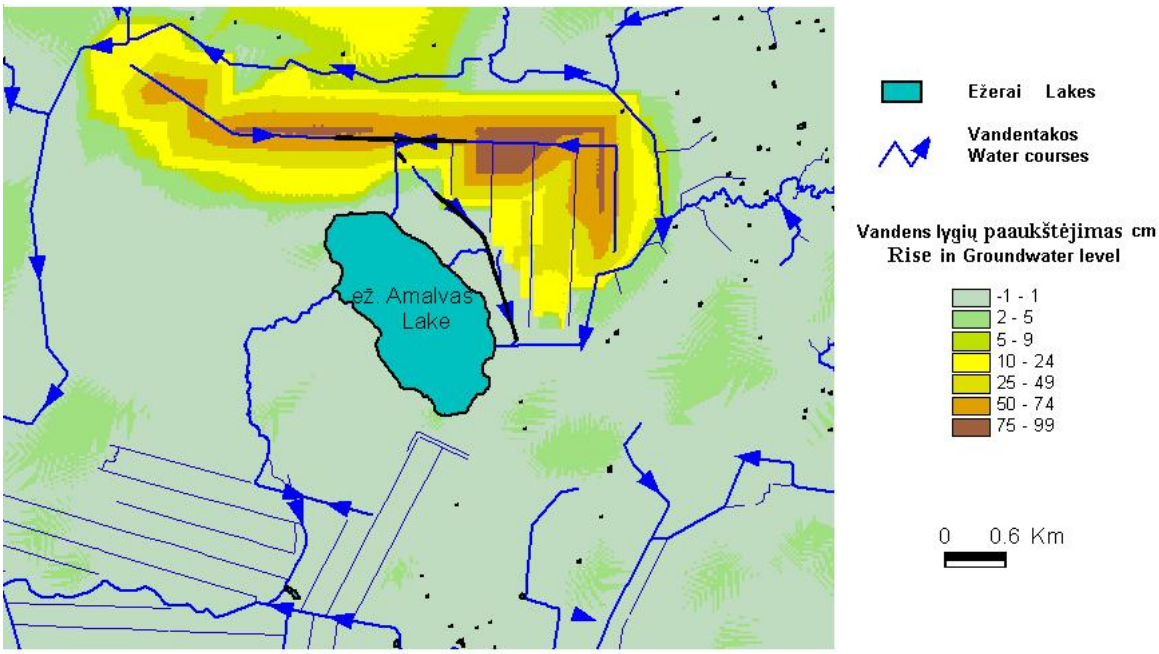

Fig. 4.27 The average rise of groundwater level in Amalvas polder during summer season after the restoration of connection with the lake (in comparison with scenario "0")

The simulation carried out according to such scenario showed that groundwater level in Amalvas polder during winter would rise up averagely by 60 cm and in summer – by 50 cm in comparison with the same period according to scenario "0" (Figs. 4.26-4.27). The rise in some places would reach 1.0 m. In the major part of the polder as well as in the northern outskirts of Amalvas wetland groundwater level would rise from 20 up to 40 cm.

5 Conclusions

1. The elimination of the sluice gate downstream of Dusia Lake would result in significant water level lowering (50 cm on average). It could deteriorate the conditions of the bank stability (in the western lake's bank) and on the bank environment with the developed living environment and recreational activity (in the eastern lake's bank).

2. Restoration of the outflow through the old Bambena River meander downstream of Simnas Lake would be an effective measure when trying to achieve naturalization of water level regime in Simnas Lake. This measure can also activate the retention of biogenic substances (phosphorus in particular) in the floodplain of the lakeside.

The positive features of the restoration of the old Bambena River meander are as follows:

- water level fluctuation amplitude in Simnas Lake would increase more than threefold;
- the outflow discharges would assume features characteristic to natural rivers (to those out flowing from lakes);
- floodplain of the river would be more effectively used for the retention of sediments and nutrients.

The negative features of the restoration of the old Bambena River meander:

- water level in Simnas Lake would decline by 77 cm on the average;
- groundwater level in the surrounding areas (within 500 m radius) during different seasons would decline from 0.15 up to 1.0 m;
- the complexity of shaping of restored outflow cross-section as well as its reinforcement because of the prevailing peat soil;
- possible worsening of ecological conditions around Simnas Lake.
- possible worsening of sanitary conditions of the territories around Simnas Lake.
- possible worsening of Simnas Lake's water quality (reduced dilution) because of the sewage inflow and/or other point pollution from Simnas town.

In order to avoid negative outcomes and to maintain the higher water level in Simnas Lake the cross-section of restored outflow can be accepted according to the demands.

3. The entire naturalization of the hydrological regime in Zuvintas Lake by removing the sluice gates built on the Dovine River is impossible. Such measure would destroy the lake. When striving for the least partial naturalization of the water regime the reconstruction of the sluice gates is necessary.

4. Scrubs and trees in the complex of Zuvintas and Amalvas wetlands significantly lowers the groundwater level. The highest impact is estimated in the areas of coniferous woodland during summer season. After the removal of the scrubs and trees, the water level can rise from 0.03 up to 1.0 m. During winter time the water levels in Zuvintas and Amalvas raised bogs would rise from 1 to 90 cm. The removal of vegetation would not have any significant impact upon the water level dynamics in Zuvintas and Amalvas lakes.

5. The rise of groundwater level at the outskirts of Zuvintas and Amalvas wetlands can be achieved by raising the water levels in the draining ditches by means of small dams or bars. Such small dams in the ditches would raise the groundwater level by 0.6-0.7 m on average on the northern, north-western and the north-eastern edges surrounding Zuvintas wetland. The maximum rise in water level can reach more than 1.0 m. The introduction of the small dams can affect the territories situated at a distance from 100 to 1000 m. The dams in the ditches would affect the area of the drained Amalvas raised bog in particular. There the groundwater level would rise by 0.6 m on average.

6. The entire naturalization of the water regime in Amalvas Lake is possible only after the removal of the sluice gates built downstream of the lake. However, the introduction of such measure is unacceptable because it would lower the water level in the lake by more than by 1.0 m. In order to at least partially naturalize the water regime in Amalvas Lake the sluice gates should be reconstructed.

7. The entire naturalization of the water regime in Amalvas polder is possible only after the removal of the pumping station and the restoration of the direct connection with Amalvas Lake. Consequently, the water regime in the polder would be directly related to the water level fluctuations in the lake. Partial and periodical water logging is likely to occur. During summer season the groundwater level in the polder would be close to the ground surface. Agricultural conditions would worsen significantly.

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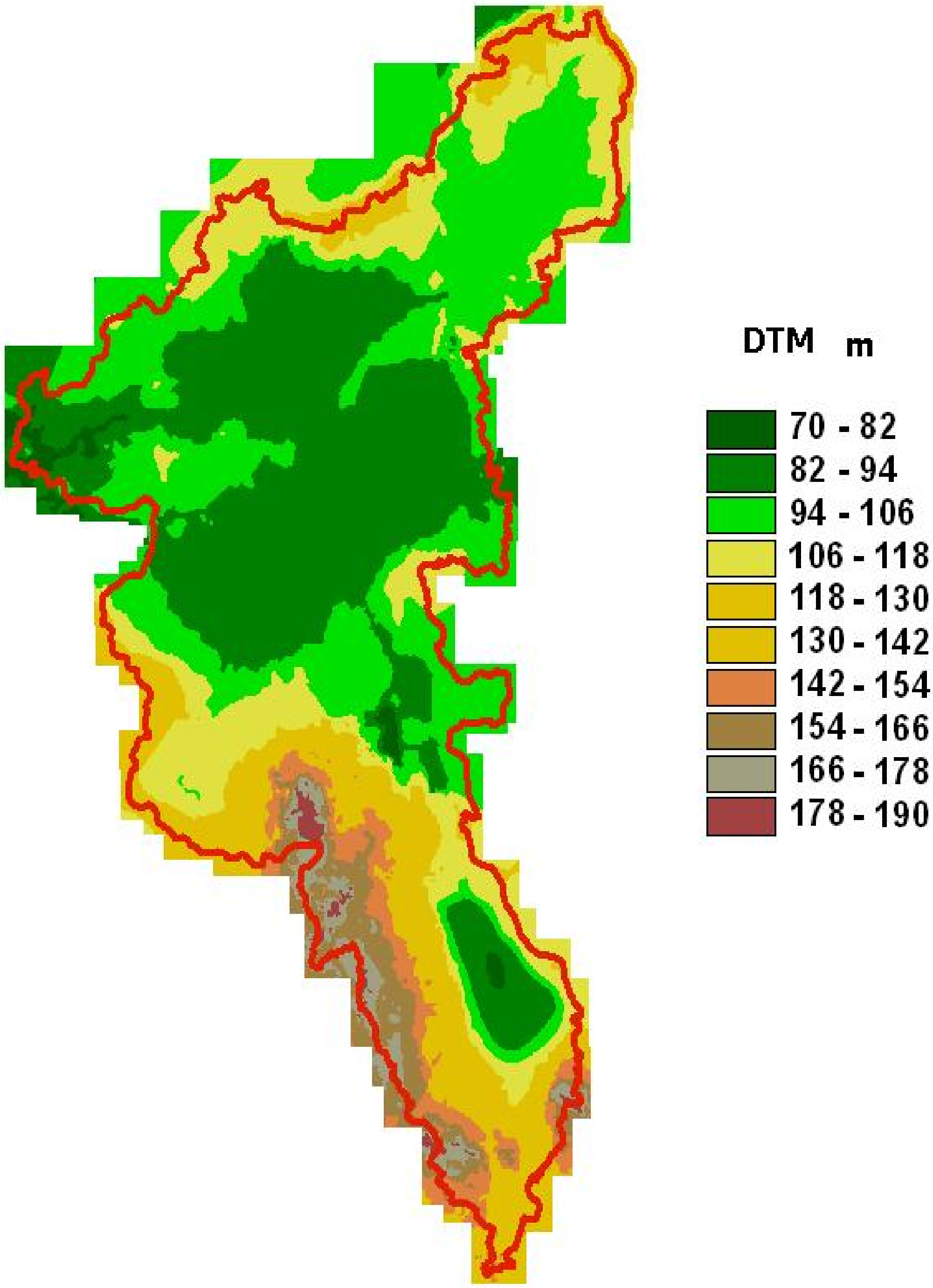
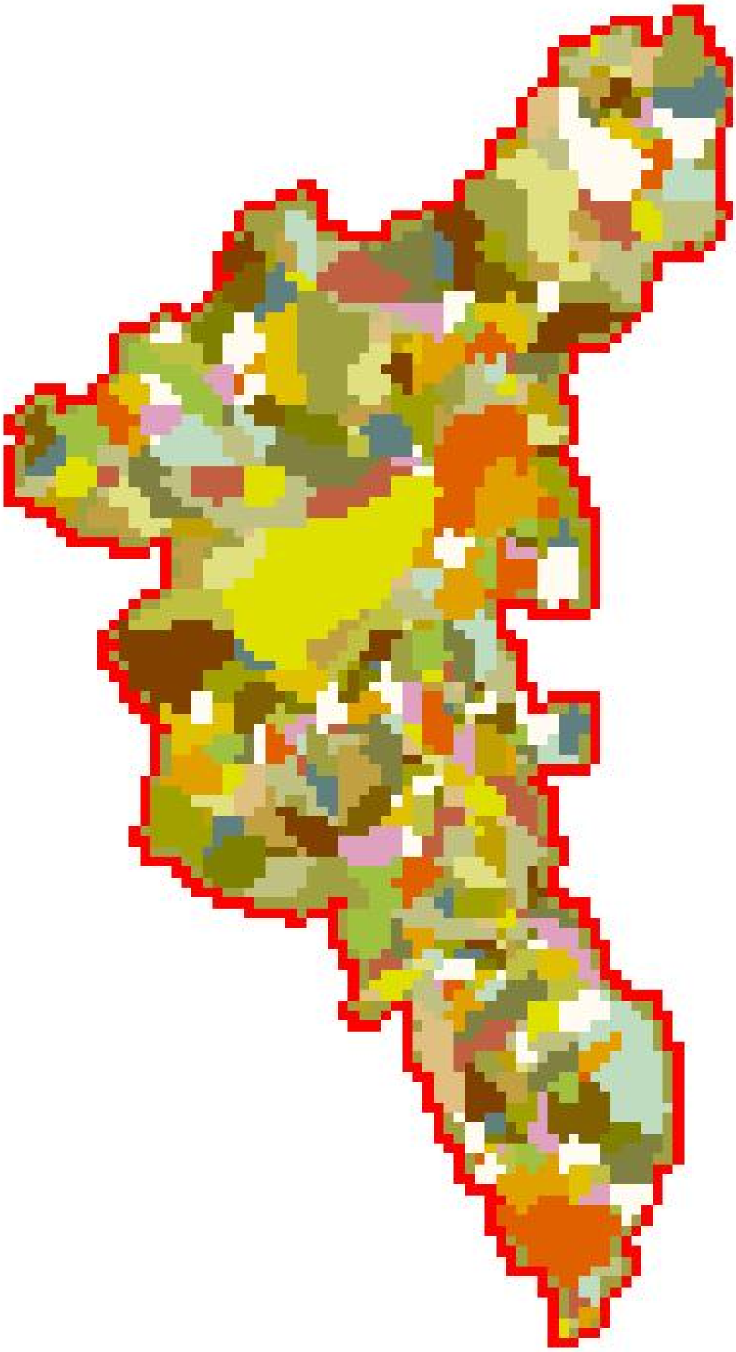
Appendix 1



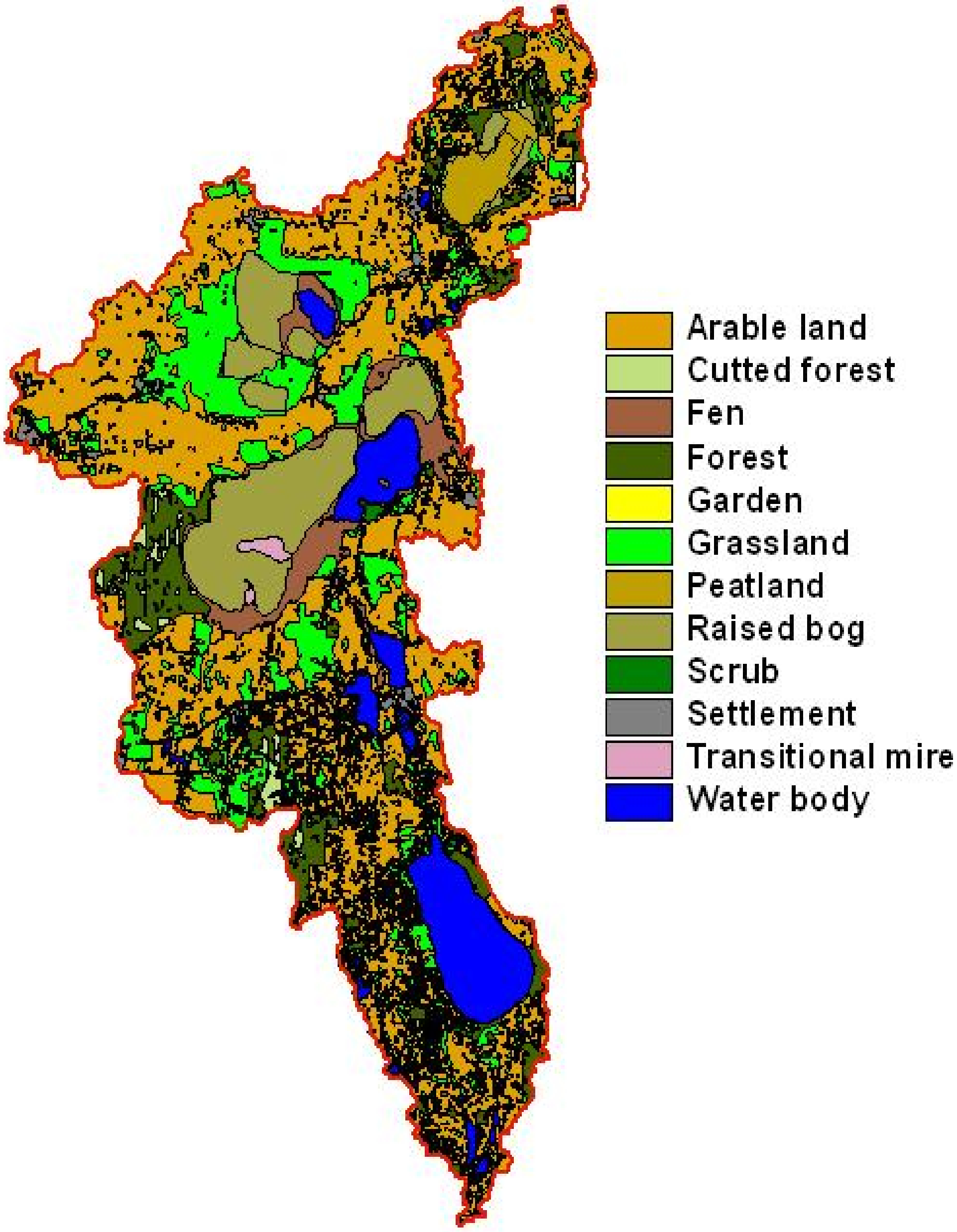
DTM of the Dovine River Basin

Appendix 2



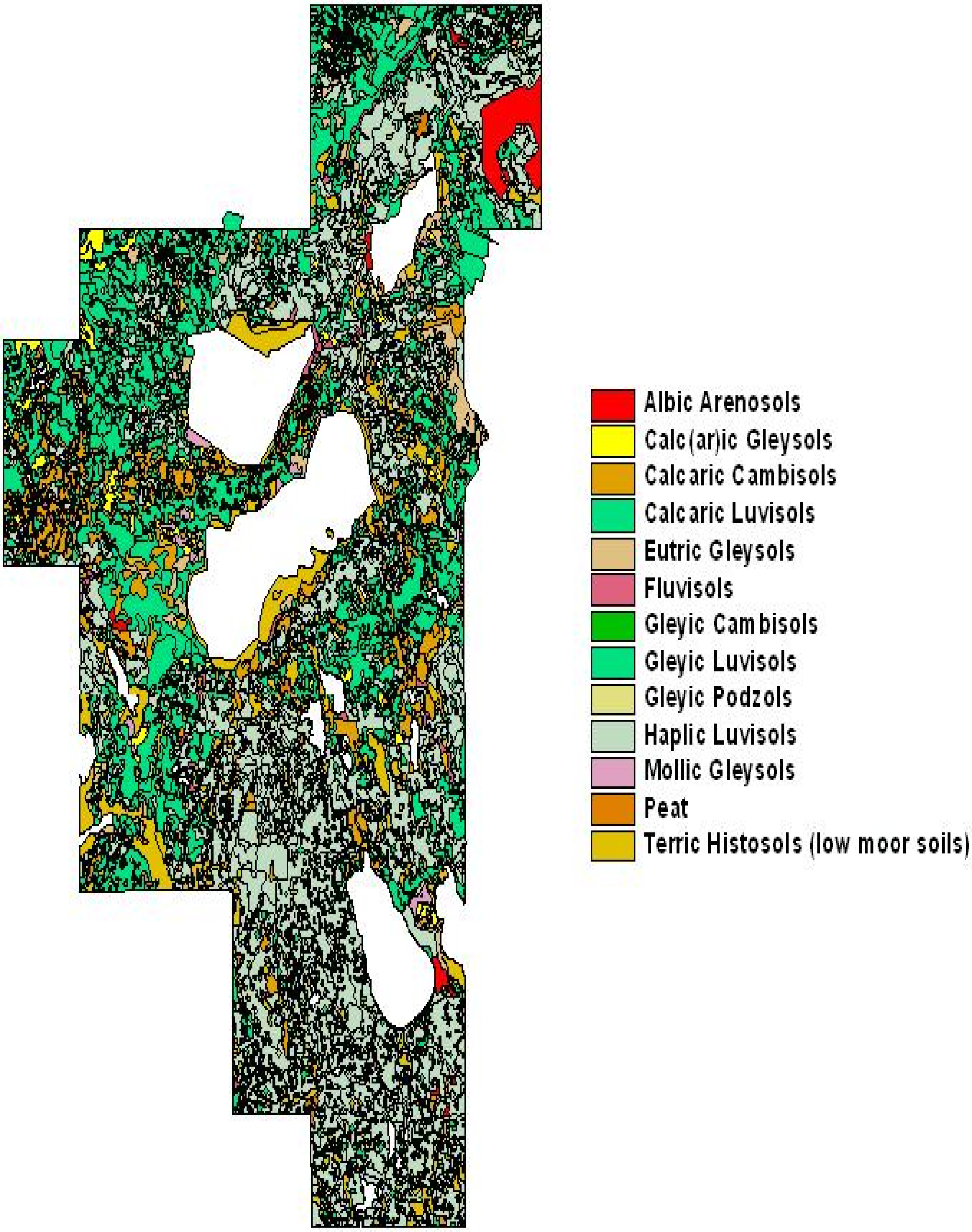
Boundaries of the Dovine River Basin along with sub-basins

Appendix 3



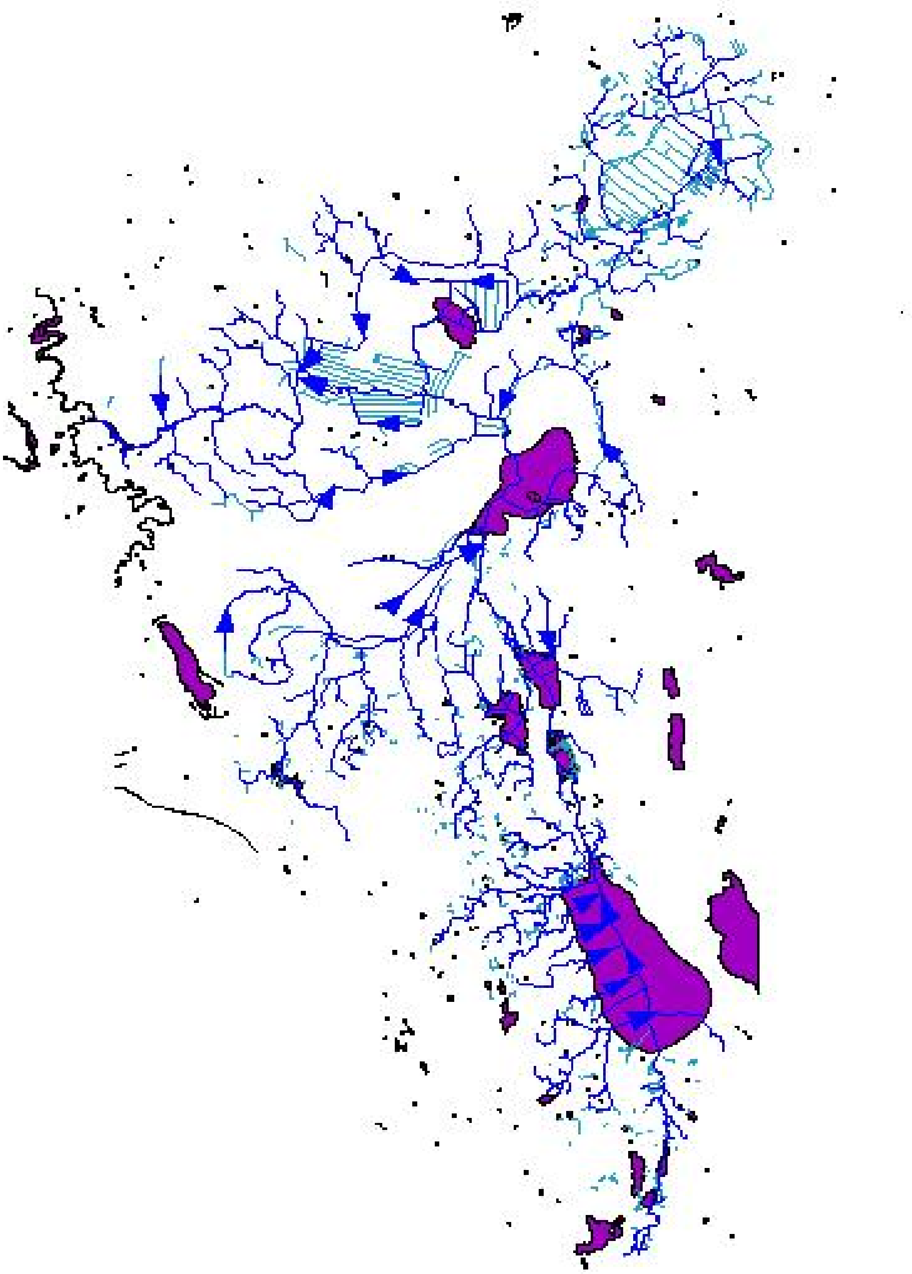
Land use in the Dovine River Basin

Appendix 4



Soil types in the Dovine River Basin

Appendix 5



Hydrographical network (watercourses) in the Dovine River Basin