Scientific Papers. Series A. Agronomy, Vol. LVI, 2013
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

HYDROMELIORATIVE SOLUTIONS FOR IRRIGATION AND DRAINAGE OF VINEYARD IN NORTHWESTERN BULGARIA

Krasimir TRENDAFILOV, Violeta VALCHEVA, Stefka TODOROVA

Agriculture University, 12 Mendeleev Blvd., 4000, Plovdiv, Bulgaria

Corresponding author email: trendafilovk@mail.bg

Abstract

The present work is a project for water supply and partial drainage of vineyard covering an area of 17.13 ha, located in the village Rayanovtsi, municipality Belogradchik in northwest Bulgaria. The aim is to provide the water quantities needed to supply drip irrigation system of the vineyard. It was designed and constructed a system for partial subsoil pipe drainage for discharging of excess groundwater, causing waterlogging of part of the terrain. Collected drainage water is important as an additional source, providing certain autonomy in the water supplying of the object. Performance of the tasks of this project is limited to applying a complex of technical-meliorative and hydromeliorative activities aiming to improve the drainage conditions in the non-drained part of the vineyard and to provide the necessary water amounts for the irrigation. In this paper are compared theoretical water balance calculations with the actual results from the first year of operation of the installation.

Key words: *drainage, irrigation, vineyard.*

INTRODUCTION

The following article represents a conceptual phase of a project for water supplement and partial drainage of vineyard with area of 17.13 ha, located in the northwestern part of Bulgaria – Rayanovtsi village, Municipality of Belogradchik. Project presents a bipartite acting ameliorative model in which with one technological solution is achieved solving two tasks:

- Drainage of a part of already established vineyard, where it is ascertained a periodic surface waterlogging.
- Independent emergency water supplement of vineyard as thus is provided the minimum required amount of water during the periods of extreme draught.

Dual-functioning drainage-irrigation system in this site is built after a preliminary hydro-geological observation in which is determined that the vineyard lies on a powerful granite, which is characterized limited drainage. The lack of alternative water sources and the low filtration capacity of the granite weathering materials, suggest us to the idea of building a drainage system, where the drained water is used for simultaneous emergency irrigation, while all elements of the system are assembled within the boundaries of the vineyard, without interfering with the common maintenance practices.

MATERIALS AND METHODS

Characteristic of the region

The vineyard is established in a region which geological structure is presented by a granite massif (Zagorchev et. al., 2009). The upper part of the massif at a depth up to 3.8m is highly weathered and gleyic (Figure 1). It is presented of sandy clays with single angular gravel, part of the primary rock. Under sandy clay elluvial material at depth up to 7-8m, is registered cracked and weatherd zone presented by angular gravel with sand filler. From 8 m to 38 m, during the drilling in the granite massif is separated zone of regional crack structure, characterized by sections of solid rock, alternating with cracked areas with thickness of about 0.5 m. At depth under 38 m, the massif is presented by dense and very solid granite, which strength increases in depth. Regional regularities of the section define it as part of the structure in which groundwater flows downward within a system of large and small cracks.

The relief of the region is slightly truncated. The main slope is east-southeast. Horizontal roughness of the relief within the whole site is

30 m. Regarding the formation and distribution of the flow the terrain is divided into two parts:

- Zone of a transit flow-mainly covers sites with a slope of more than 30. The soils in this area are well drained. Some of them are shallow and are formed on solid rock, forming water shields.
- Non-draining zone-covers enclosed shallow accumulative relief forms in the northwestern and central part of the terrain and routes of accumulation of groundwater flow, appearing to be stirred in east-west direction.

The groundwater flow cotters in described non-draining parts of the terrain. Poor natural drainage is naturally determined process. It is responsible for the formation of light grey forest soils with a strong contemporary hydromorfizm.

Described soil types have relatively heavy texture that determines the compaction of sobsoil. Waterlogging of surface horizons occurs periodically during the winter and spring.

From the surface downwards, the system could be considered as a hydraulically connected network of three zones.

Zone with thickness of 0.5-4 m composed of sandy clay. The zone has a low filtration features but not strong shielding role as regards to the infiltration of rain water. In sections where this zone is composed of more sandy varieties with small thickness, can be considered as a zone of aeration with juvenile waters, i.e. zone with periodic waters in which the water infiltrates vertically to the water table.

The gleyzation of feldspars acts as a water shield layer, creating pressure conditions for groundwaters. In clayey sections the zone is characterized by low water conductivity properties (k = 0.01-0.0001 m/d), while in areas with presence of more sand and gravel conductivity increase (respectively k = 0.5-0.01 m/d). By expertise for the intensity of infiltration recharge can be assumed value of 5.10^{-5}-$1,10^{-3}$ m/d.

Weathering crust from the zone of local cracks. Represents a dense network of micro and meso cracks. Its thickness is about 25-40 m, depending on the degree of weathering of the massif. During the hydrogeological observation of the massif in the middle of its body, was established a long watered zone. From the hydrodynamic point of view hydrogeological medium of this zone can be considered as heterogeneous and anisotropic hydraulic uninterrupted layer. The filtration ratio of the zone is about 1.10^{-4} to 5.10^{-5} m/d.

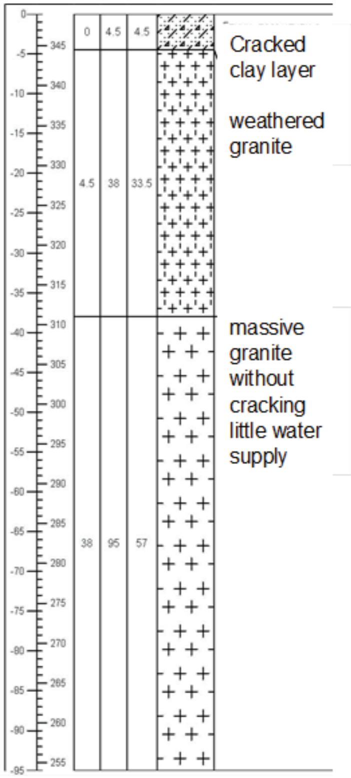

Figure 1. Research drilling column of the massif

Zone of deeper lying cracks. Water in them flows through cracked and weathered zones. Probably part of weathered cracks are affected by hydrothermal changes leading to gleyzation. Such zones have a barrage effect on the flow dynamics. Typical for the zone of regional cracks is the absence of one continuous piezometric surface. Therefore in hydrodynamic aspect the medium can not be considered as continuous. Approximation of the medium and solutions for the movement of water in it, can be searched solely by applying of numeric methods of analysis using the method of 'finite elements', and only in the cases when it is clear the geometry of the sections.

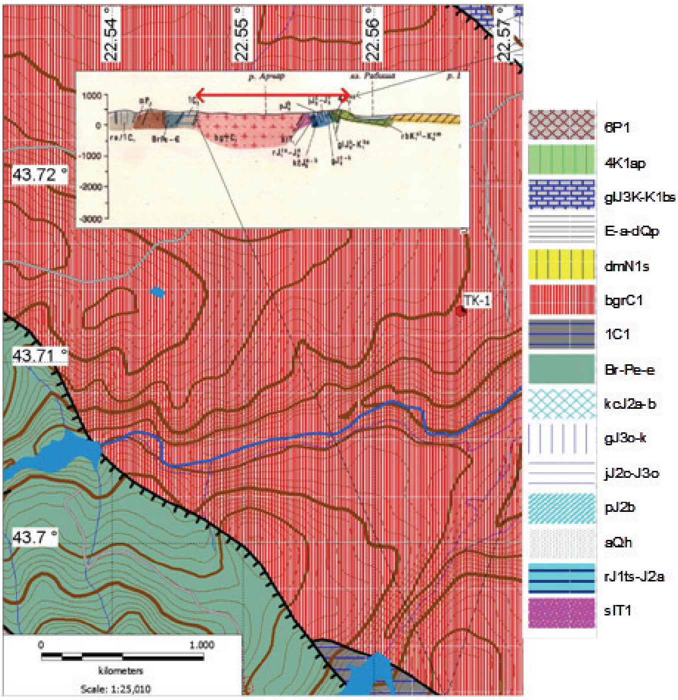

Figure 2. Geological map of the region. 6P1 – Volcanic rocks; 4K1ap-Urgonic limestone; glJ3K-K1bs-West Balcanic calcaric group; E-a-dQp-eolic alluvium and delluvium clay; dmN1s-sands, sandstones and detritussic limestones; bgrC1-Belogradtchik plutonite; 1C1; Br-Pe-e-gray and green shale; kcJ2a-b-diabases; gJ3o-sandstones; jJ2c-J3o-limestones; pJ2b;-sands and clays; rJ1ts-J2a-alluvium; slT1sandstones

Figure 1 shows geological column for the layout and depth of impermeable granite layers, and the Figure 2-sector of the geological map of Bulgaria showing the location of the terrain within the boundaries of granite plutonite.

RESULTS AND DISCUSSIONS

All research activities are focused on two general courses – first determining water supply capabilities of groundwaters, and second determining zones with water supply rates, sufficient for providing flow in the drainage canals.

The first task is solved through the implementation of exploratory drilling (Figure 3). To determine the hydrogeological properties of the medium, respectively, its filtration characteristics is carried out an experimental water extraction.

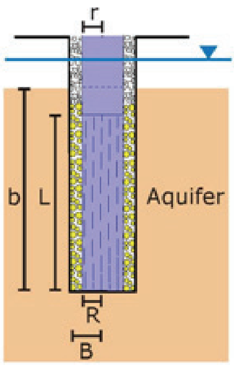

Figure 3. Scheme of exploratory column

In analyzing the results of the water extraction experiment the first eleven minutes from the start were ignored, due to low water extraction and conductivity of the medium. During the water extraction with flow rate of 0.7 l/s in the first eleven minutes the pump runs out the water from trunk, while the influx of water from the water supplying horizon is

considerably less. These facts are proven by the arrangement of the experimental results in this time interval in a straight line rather than in parabolic form, as would be normal.
Regarding the analysis of the results from the water level recovery, the first four minutes are disregarded, in order to remove the effect of the returned in the hose water in the drilling after stopping the pump.
The results of filtration experiments are shown on Figure 4. After summarizing it was concluded that in the medium around the two drillings, the conductivity is about $4.5x10^{-3}$m/d. Water supply of the medium is about 1.3% (0.013). Its determination by the described manner we consider to be correct, since the experiment was conducted after dipping the pump directly into the drilling trunk – no filter zones were blocked. The drilling is regarded as ideal and that exploits the whole water supply zone, after it has considerably penetrated vastly into a solid massif. Data shows the average daily water capacity of the facility is 0.06 l/s.

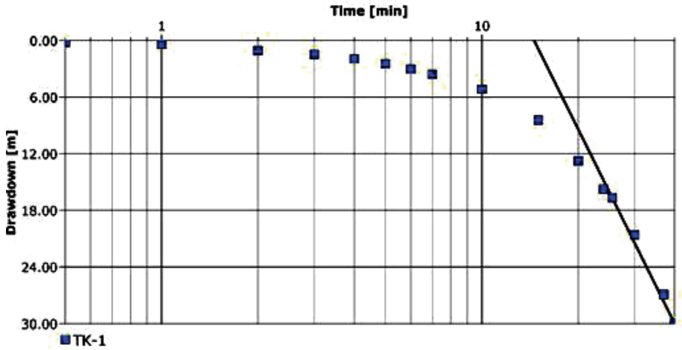

Figure 4. Results from a water extraction from drilling TK-1. Logarithmic time diagram

The main characteristics of the soil in the surface horizon are shown on Table 1. The presented data regards an average soil sample, representative for the layer in depth of 1m. The table shows that the soil is with heavy texture, where the clay and silt particles are dominant. Fine clay is about 25% from the contents of the physical clay. Water filtration ratio of the soil, measured in uninterrupted column at a pressure of 20 kPa, after reaching equliribrium water movement is low – 0.24 m/d. This limits the zone of action of the drainage pipes up to 12 m in both sides of the trace. In order to increase the radius of action we adopted height of the filtration bank to the level of the terrain. In destructed soil after reaching a bulk density of 1.4 g/cm3 the filtration ratio increases to 0.65 m/d.
Time for reducing of level to the set of drainage suction rate is 8 h. The height of reduced water level is estimated at 1.5 m, with a coefficient of water supply of 0.124.
The situation and the topography of studied terrain are shown in Figure 5. At the same scheme are given the traces of the drainage suction velves. They form a hydraulically connected network. Depending on the location of drainage canals, they function as canals for drainage of internal and external, regard to the limits of the terrain waters. Canals for the drainage of external waters are located at the borders of the terrain and cross the surface and shallow subsurface flow, as simultaneously they drain the adjacent zones of waterlogging. Canals located inside the terrain drain near lying groundwater in waterlogged zones. The direction and situation of drainage canals are in accordance simultaneously with the direction and position of the rows in the vineyard and with the local terrain topography.

Table 1. Soil characteristics

Parameter	Measure	Value
Physical clay (< 0.02mm)	%	56.6
Fine clay (< 0.002mm)	%	12.2
Arithmetic mean diameter of soil particles		17.10
Specific density in the level of drainage suckers, d	t/m^3	2.56
Bulk density in field capacity	t/m^3	1.37
Porosity	-	0.46
Filtration ratio before sub-soiling	m/d	0.24
Filtration ratio after sub-soiling	m/d	0.65
Average coefficient of filtration for the drainage layer	m/d	0.61
Time for reducing of water level	h	8.0
High of unreduced water level	m	1.5
High of reduced water level	m	0.6
Coefficient of water supplying	-	0.04
Depth of pipe laying	m	1.2

Figure 5. Situation and topographical plan of the drainnage canals

Table 2. Hydraulic dimensioning

Parameter	Volume	Dimension
Dimensioning module of drainage flow	0.83	$l/s/km^2$
Dimensioning the maximal area of drainage	21000	m^2
Dimensioning water quantity	17.43	l/s
Diameter of pipe	0.110	m
Wetted perimeter	0.35	m
Hydraulic radius	0.03	m
Roughness Y	0.02	
Speed coefficient, C	79.34	
Speed of open canal flow	0.211	m/s

The transverse profile of the drainage suckers is shown in Figure 6. Data from the hydraulic dimensioning of the drainage system are given in Table 2.

Canals are dug with a rotary trencher, at a depth that ranges between 0.70 and 1.50 m, depending on the longitudinal profile of the terrain. The depth of the trench along the whole trace exceeds projected depth in the corresponding section. Thus, the precise levelling of the bottom is achieved by filling of sand cushion. Sand layer is levelled manually and compacted to 14 KN,dm^{-3}. Precise levelling up to ± 0.01 m is completed in each 5.00 m along all traces. On the sand layer are laid corrugated drainage pipes with perforation at 270º of the transverse profile. The diameter of the pipes is accepted everywhere along the project traces at 100 mm. At this size and in set with the measurements of longitudinal profiles gradients is accepted a drainage capacity exceeding the designed hydraulic loadings. Additional capacity for increasing hydraulic radius of the drainage system is expected to be obtained from the sand-gravel filter backfill that fills the free volume of the transverse profile to the surface. By laying of the backfill the system drains both surface and near laying groundwater.

The application of the system over the water shield on the sand cushion produces imperfect work regime of the drainage system along the whole trace.

In this way is achieved an increase in the radius of drainage action if it is kept the condition for sufficiently low hydraulic resistance in the drainage canals. The calculation is made by Manning's formula for free-surface flow (Dooge, 1992). Water from drainage pipes is collected in a tank with a volume of 45 cm^3 cubic meters and from there are pumped under pressure and transferred to the main water reservoir with volume 987 cm^3. From this tank water is used for irrigation of vineyard during the periods of extreme drought with an automated drip irrigation system. Block scheme of the facility is shown in Figure 6.

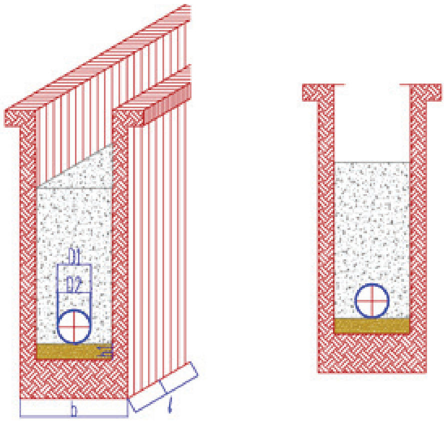

Figure 6. Transverse profile of the drainage sucker

The implementation of the projected ameliorative system begins with building of a discharge facility in the sedimentation pits. It is implemented from prefabricated elements. Drainage discharge includes manhole shown on the same drawing (Figure 7).

After the construction of the discharge installation is traced and excavated the route of the local collector in its part outside the existing vineyard. Hand trench of the rest of the collector is consistent hydraulically and is implemented after completion of excavation works. The final design and levelling of the trench is made after its full realization.

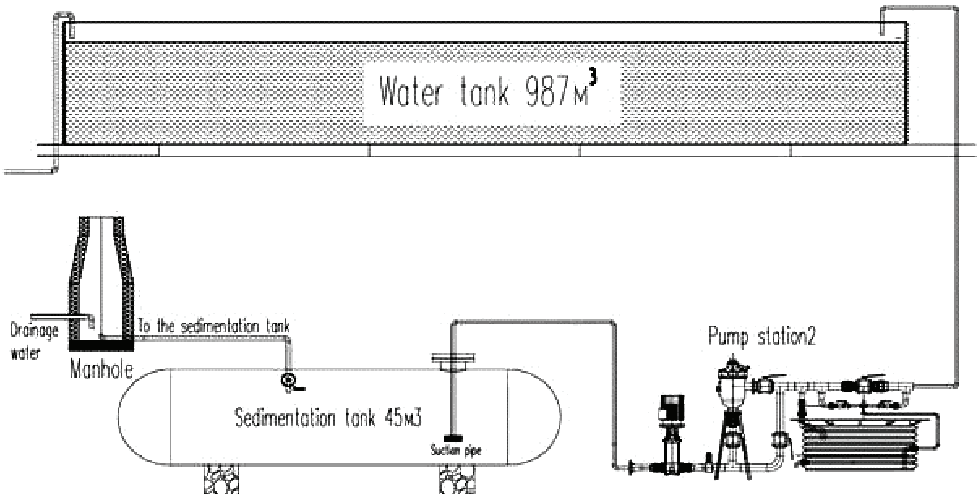

Figure 7. Block scheme of the system

CONCLUSIONS

The technological decision for construction of drainage system with possibilities for collecting water from the drain flow is a high tech meliorative solution that can be created in relatively rare cases when the high level of groundwaters during winter is combined with strong and extremely dry summer.

In its construction should be borne in mind that the collected water flows in all cases is insufficient to cover the requirements of plants and to ensure normal irrigation regime. In this case constructed meliorative bypass system can cover about 15% of the estimated quantities of water from which the plantation needs in extremely dry years.

In practice this means that in the course of vegetation can be realized one watering, with rate of about 15 dm^3 per vine. This amount of water should be applied within the period of growing of grapes, when there is maximum water need in conditions of the highest evapotranspiration of the plantation.

REFERENCES

Dooge J.C.I., 1992. Channel Wall Resistance: Centennial of Manning's Formula, edited by B. C. Yen., Water Resources Publications, Littleton, Colorado.

Gjurov R., Berberova1 R., 2011. Georadar and geological researches-Vaskovo village area, IIIth annual international conference "Ecologization 2011", Bulgaria.

Zagorchev I., Dabovski H., Nikolov T., 2009. Geology of Bulgaria, Vol. II: Mesozoic geology Academic press "Prof. Marin Drinov", (Bg).