# THE ABANDONED BLOCK-CUT PEAT EXTRACTION FIELD INFLUENCE ON THE NATURAL RAISED BOG HYDROLOGICAL REGIME

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**Abstract**
Peat is still mined in many parts of the world for production of peat substrates and energy. Many peatlands were affected by drainage in the past also for forestry and agricultural needs. Nowadays a raised attention to peatlands is focused, especially to drained peatlands due to their carbon reserves and their potential influence to the climate on the one hand, but on the other hand - due to raising awareness on protection of environment, habitats and biotopes. There are many examples on restoration activities in peatlands found worldwide, especially their water regime is the subject of regulation, which plays the major role to bring back original functions. In most cases in Latvia as the aim for protection and restoration of degraded peatlands was protection of EU biotopes and habitats. Of course, peatlands play an important role in emissions of the greenhouse gases $CO_2$, $CH_4$ and $N_2O$, produced during mineralization of the drained peat organic matter. In literature, we can find only few cases where hydrological regimes are described for natural raised as well as restored block-cut peat extraction fields. This research analyses block-cut peat extraction field water level fluctuation influence on naturally raised bog hydrological regimes. Hourly data is analysed for six groundwater monitoring wells as well as for determination needs of water level fluctuations in excavated peat quarry as a response to precipitation.
**Key words:** Hydrological regime, block-cut peat, bog.

## Introduction

The bog is a poorly drained usually acid area rich with accumulated plant material, with specific flora and fauna (Walker & Lowe, 1981; Nusbaums & Rieksts, 1997; Holden, 2009). The world's bogs cover around 3% of the total land area, but in Latvia even approximately 10% of the total land area is covered by bogs (Nusbaums & Rieksts, 1997). The bog formation is very important component of carbon, nitrogen, water and other substances in biogeochemical cycles (Brown, 2000). Latvian bog classification is mainly determined by the water regime and vegetation. Three groups of bogs are classified: a raised bog or high moor; transition mire, transitional fen or mixotrophic mire; fen or minerotrophic mire (Overbeck, 1975). In Latvia, raised bogs are mostly formed on watersheds of catchments in plains and lowlands (Brakšs, 1961). During accumulation of peat layer the central part of a bog rises above the surface (Edom, 2001). A raised bog is one of the most important terrestrial ecosystem, which acts as significant carbon accumulator, stabilizes water regime, reduces nutrient run off and plays significant role in climate regulation (Bragg, 2002). Although bogs make up only 3% of the land surface of the world, they contain 30% of soil carbon. Raised bogs hydrological regime is determined by precipitation, surface water and groundwater (Laitinen *et al*., 2007). Raised bogs are characterised by accumulation of precipitation in dome thus supplementing surface waters and groundwater in surrounding areas (Price, 1996; Edom, 2001; Bragg, 2002). Raised bogs are significant water accumulators. Bogs consist of 89-94% of water and only 6-11% of dry matter, which mostly consists of peat. Water is associated with peat-forming dry matter, and water flow in bog body is formatting only form free water (Romanov, 1968). Peat upper layers are characterized with relatively low decomposition level <20% and have good filtration properties; however, deeper layers - higher decomposition level and are densely compacted where water flow is rather low. Normally the water flow dominates in active layer around +0.4 till +0.9 m from bog surface level (Romanov, 1968; Маслов, 2008). The water flow at active layer of raised bog regarding characteristics is of dual nature: surface water and groundwater. This active layer also incorporates activity of surface water and groundwater runoff, which determines the water level in the raised bog. Raised bog hydrological regime and runoff fluctuate naturally. By increasing the size of a bog dome, a link with groundwater declines. However, more significant changes are caused by digging ditches in the raised bogs thus promoting the water outflow out of the dome. Ditches are splitting active layer, intercept therein water and drainage in bog domes are becoming more rapid. Within ditch influence zones there are significant increases of water level fluctuations.

- Normal groundwater regime in raised bogs is from +0.15 to +0.20 m;
- Disturbed groundwater regime amplitude in raised bogs may exceed ± 1 meter (Delina, 2011).

In study area more than fifty years after peat extraction drainage ditches in the edges of quarries are still functioning and are affecting the hydrological regime of the raised bog. As a result of more than fifty years drainage, the peat decomposition is elaborated; more active compaction takes place and invaded vegetation comes in raised bogs. Peat extraction has left significant amounts of degraded areas and territorially separated the Zalais bog and Caukciems bog domes. Peat pits sites are developed as two water reservoirs of Zalais bog (Purmalis, 2014). The water level in the peat layer of natural part of Zalais bog is only slightly below the bog surface and is characterized as normal raised bog water level regime. Two peat pit and ditch drainage systems with a run off to Slocene River and the Baltic Sea significantly influence bog hydrological regime (Purmalis, 2014).

In literature, we can find several studies of affected peatlands, but there is limited knowledge about former mining quarries effects to hydrological regimes in raised bogs. The aim of this research is to identify the distance of disturbed hydrological regime of raised bogs affected by block-cut peat extraction fields.

**Materials and Methods**

*Zalais Bog*

The research was performed in the Zalais bog near Kemeri National Park nature reserve, around 3.5 km east from Smarde village in Latvia. It covers an area of 1,586 ha, most of them (1,047 ha) are occupied with raised bog, transition mire takes 286 ha and minerotrophic mire - 253 hectares. Raised bog maximum peat layer thickness is 6 m, the average depth of the peat layer is approximately 3.3 m. In 100 ha of Zalais bog area from 1950 to 1960 the drainage and peat extraction works were performed. A peat extraction quarry was developed there, and the western part of the bog was drained. The drainage flow was redirected to Smirdgravis (Sera gravis), which discharges in the Slocene river. A block-cut peat extraction method with having two peat excavation pits and water pumping station was used. Peat was extracted in two pits with a length of 2.35 km and 1.20 km and a width of 120 m and 130 m respectively (Fig. 1). In 1960, peat extraction works at Zalais bog were interrupted and the area included into the Kemeri resort sanitary protection zone, because of hydrogen sulphide minerals formation process under Zalais bog peat layer. Currently, drainage ditches with the length of ~300 m each are functioning around water reservoirs. Although there are monitoring wells in edges of water reservoirs, hereby we analyze only hydrological regimes in the bog part without drainage ditches (direction of south-east).

**Data collecting**

In the territory, six chemically inactive perforated PVC monitoring wells with the length of 2 m and

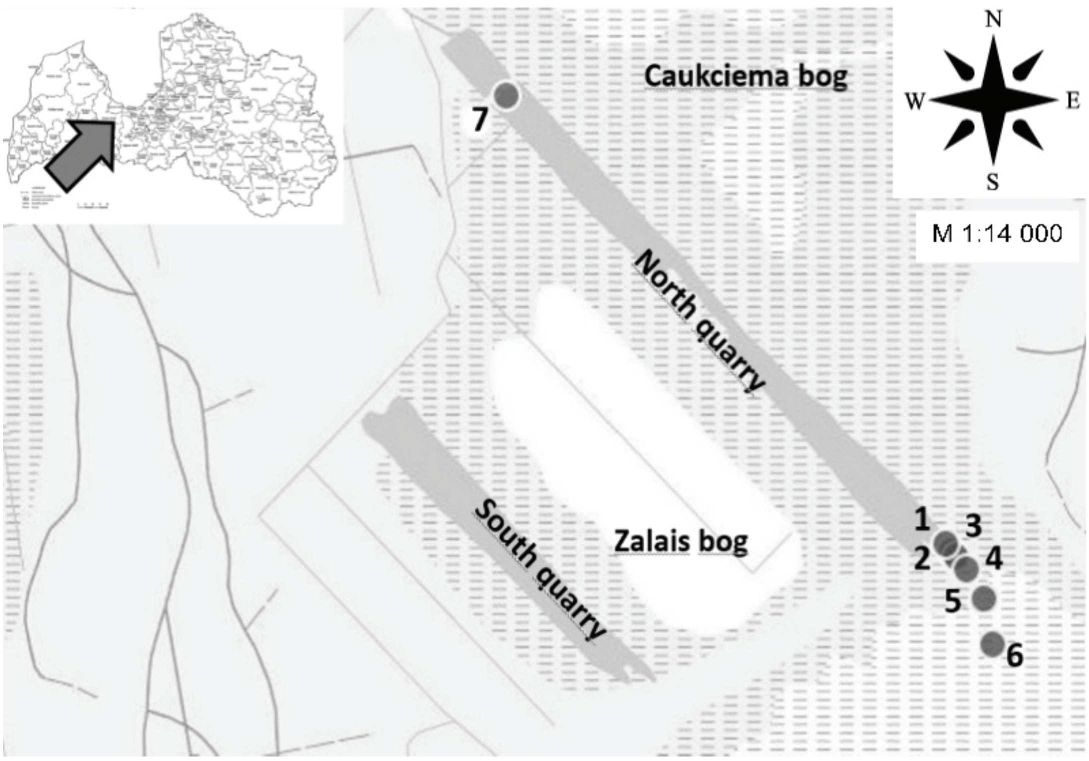


Figure 1. Location of Zalais Bog and water level monitoring points.

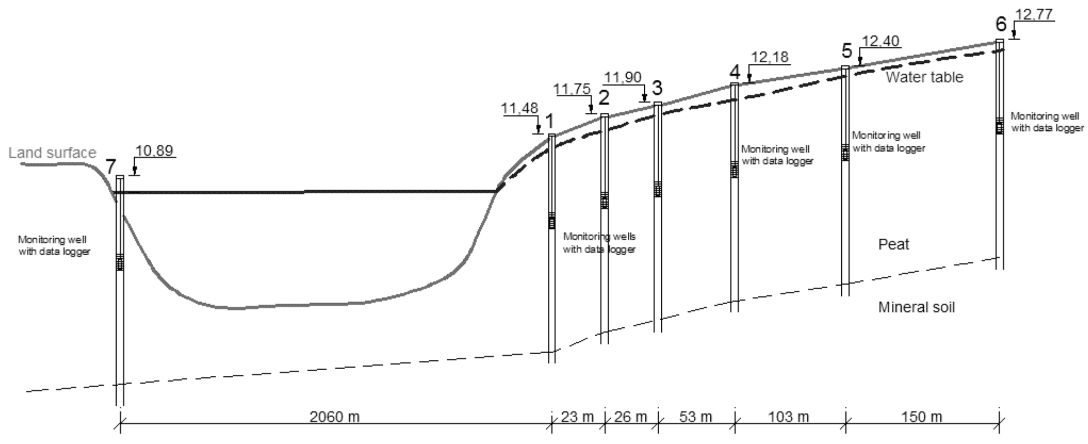


Figure 2. The scheme of monitoring wells and relative heights of water level peat quarry.

diameter of 50 mm were established. Additional points of study in peat quarry pond were established. Hydrological monitoring data were collected with the frequency of each 30 minutes by using Mini-Diver data loggers with barometric diver to compensate fluctuations of atmosphere pressure. Data treatment was performed by using Diver-pocket software.

**Results and Discussion**

Research field was affected by peat mining and establishment of drainage ditches. Drainage system during past 60 years was working extremely well and now around water reservoirs there are functioning drainage ditches with length ~300 m each. Final succession of vegetation (mostly birches, shrubs, marsh tea) is established that is not corresponding to typical raised bog vegetation. Moreover, upper peat layers are decomposed and compressed and natural renewal of raised bog in this scenario is not prospective. First of all, a forest has already formed there, the drainage system is still operating; however, hydrogen sulphide under the peat layer is forming. In this particular case, it causes large problems as during restoration we should prevent infiltration of oxygenated groundwater. During block-peat excavation peat producers have excavated peat down

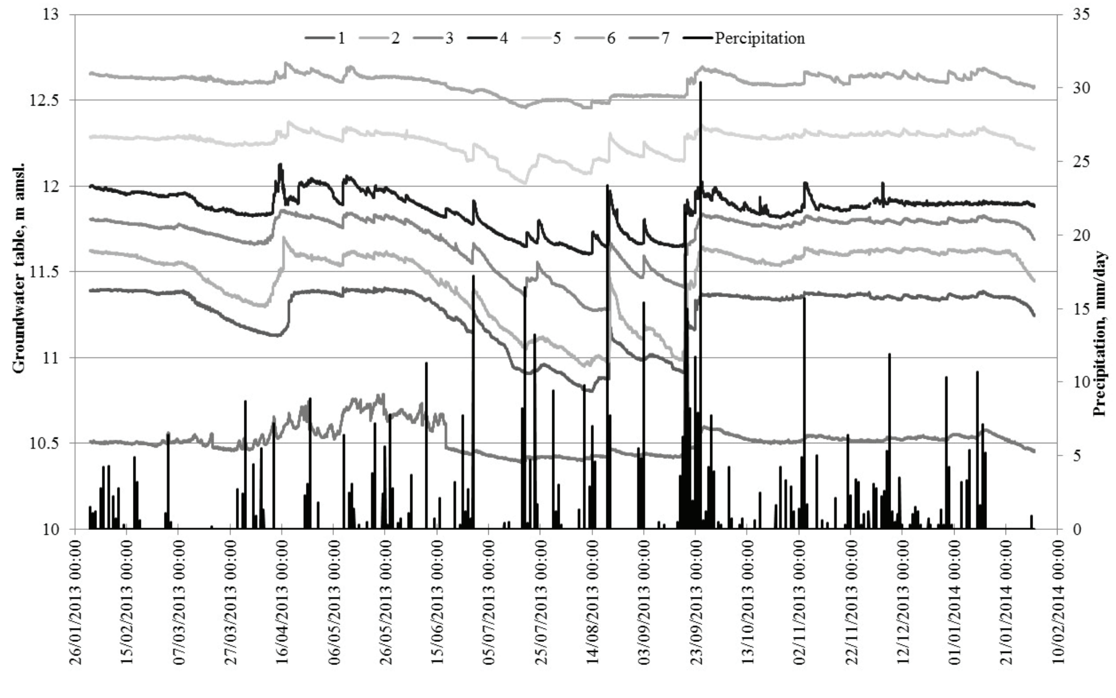


Figure 3. The groundwater fluctuation and precipitation daily rates.

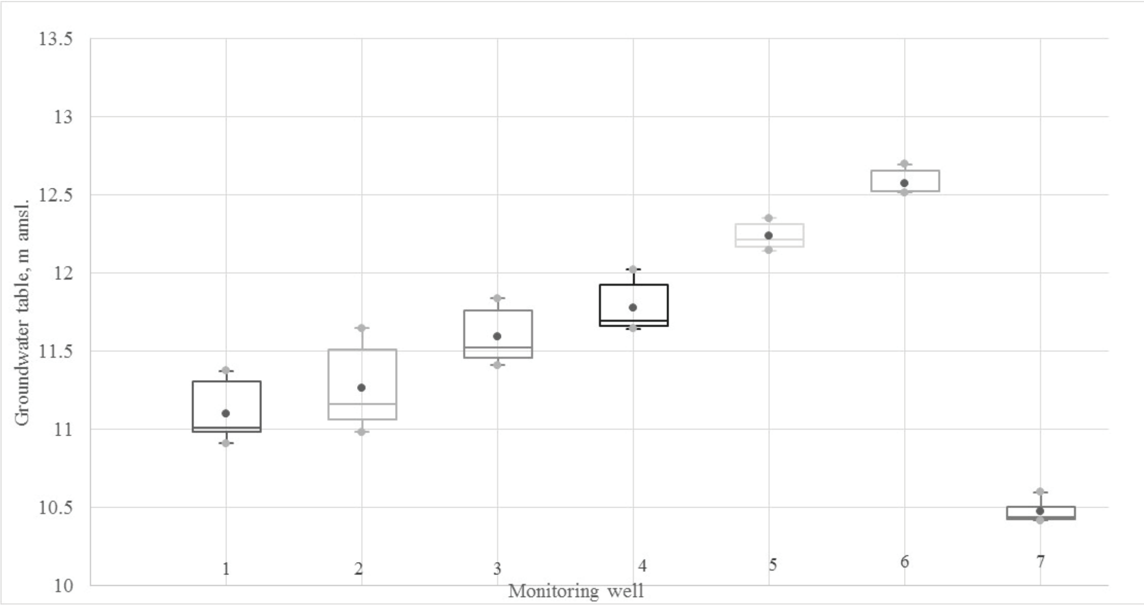


Figure 4. The yearly water level fluctuations in monitoring wells.

to the sandy bottom. In between this contact zone water conductivity increases up to 1618 μS $cm^{-1}$ and pH level to 6.1 disturbing development of sphagnum mosses. Additionally affected territory by these drainage ditches has unknown effects to hydrological regime in relatively undisturbed part of bog (direction of south-east), where there are no drainage ditches, but major influence to undisturbed bog part could be form water reservoir, especially, taking into account differences of absolute altitude to bog surface and water reservoir (Fig. 2).

Groundwater level fluctuation dependence on rainfall over the trial period from 1 February 2013 to 31 January 2014 is shown in Fig. 3. It can be concluded that the groundwater level fluctuations are closely dependent on rainfalls and dominant evaporation from bog surface rather than run-off through active layer, because even affected water reservoir shows lower response to precipitation. Of course, in this case water reservoir water level fluctuations cannot be same as bog surface, as the water regime is completely different in bogs in comparison to water reservoirs. Monitoring well No. 6 represents results of natural hydrological regime for the bog with a fluctuation margin of ± 0.27 m.

To improve understanding of groundwater level fluctuations in the period of time, we analysed annual data with the boxplot diagram (Fig.4.). From the boxplot chart we can conclude that the quarry has affected hydrological regime with gradually decreasing effect in the next few wells (No. 1; 2; 3; 4) where a wider asymmetric statistical distribution of water levels is represented. The boxplot diagram clearly identifies the area with affected hydrological regime with directly detectable influence of the quarry to the fourth monitoring well (Fig. 2.).

Paired samples Mann-Whitney (Lehmann, 1975) (Table 1) was used to determine average differences among monitoring points with control point (well no.6) and their correlation to chosen control point

Table 1

**Paired samples Mann-Whitney test results between pairs of monitoring wells in Zalais Bog**

| Pair | Mean difference | Std. Deviation | Std. Error Mean |
|---|---|---|---|
| Pair 1(Well 7 and Well 6) | 2.09136* | 0.04737 | 0.00204 |
| Pair 2 (Well 1 and Well 6) | 1.37566* | 0.11459 | 0.00493 |
| Pair 3 (Well 2 and Well 6) | 1.12282* | 0.13558 | 0.00583 |
| Pair 4 (Well 3 and Well 6) | 0.88925* | 0.08236 | 0.00354 |
| Pair 5 (Well 4 and Well 6) | 0.73739* | 0.05902 | 0.00305 |
| Pair 6 (Well 5 and Well 6) | 0.34342* | 0.02270 | 0.00098 |

*-p<0.05

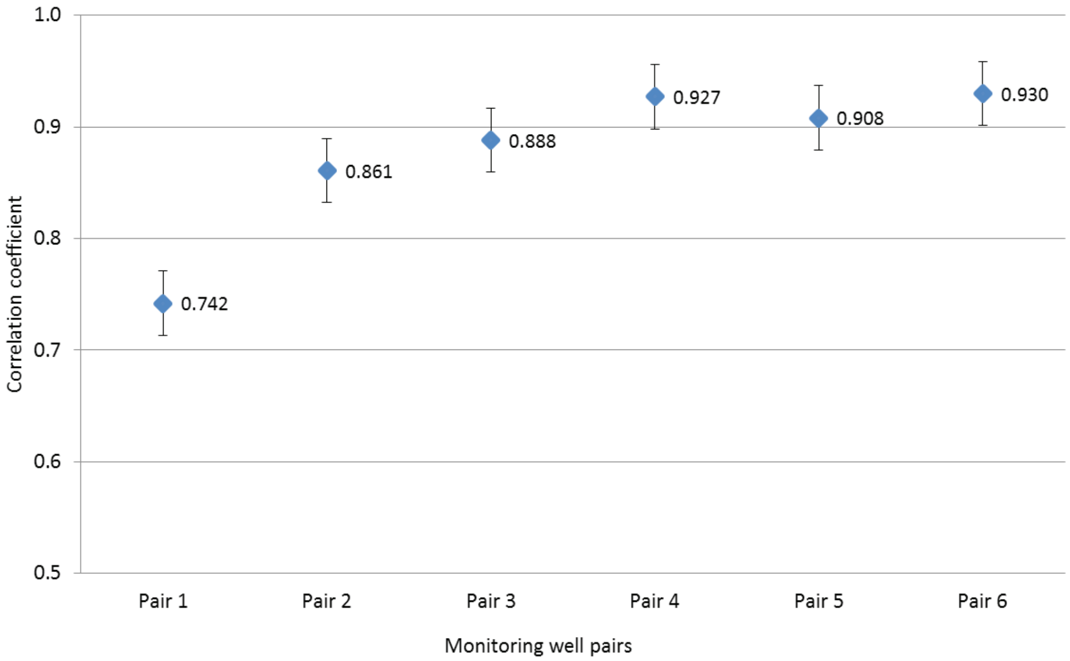


Figure 5. Paired samples correlations between pairs of monitoring wells in Zalais Bog.

(well no.6). Similarities in disturbances in hydrological regimes can be seen in boxplot diagram and paired samples Mann-Whitney as well as approved by correlations between pairs of monitoring wells (Fig. 5). Correlation between couples of wells shows that the control point (no. 6) located further away from the peat quarry has a weaker link with the other monitoring wells, showing relatively undisturbed conditions of water regime. Mean water level fluctuation in monitoring wells decreases with the distance from water reservoir, and statistically the mean value of variable per meter changes around 122 m from the water reservoir. It means that the peat quarry impact on hydrological regime of undisturbed bog falls from around 122 m distance in Zalais Bog case.

## Conclusions

Lately there is an increasing number of restoration activities for bog ecosystems as well as increased knowledge gained on restoration activities and hydrological regimes in bogs, sensitivity of these systems. Quality of biotopes and hydrological regimes for whole bog catchment basins are influenced additionally to greenhouse gas emissions due to economic activities. Nevertheless, similarities in various bog ecosystems there can be identified also plethora of differences, e.g., in Zalais Bog. There are significant differences in groundwater levels, type of vegetation, peat density and decomposition degree in undisturbed bog dome and edges of water reservoir. Even further away from explored bog areas, also in an undisturbed bog we can detect influenced water regimes, which remain affected by gravity forces due to the elevation of bog surface in comparison to the water reservoir. The decreasing influence can be identified up to 122 m from water reservoir.

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