Monitoring method for mire habitat restoration, management measures and impact assessment

The monitoring method has been developed in a framework of project LLI-306 "Conservation of biodiversity in open wetland habitats of the LV-LT cross-border region applying urgent and long-term management measures" (Open Landscape).

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Goal of the project LLI-306 “Conservation of biodiversity in open wetland habitats of the LV-LT cross-border region applying urgent and long-term management measures” (Open Landscape) is to introduce methods and tools for managing wetland habitats by engaging various stakeholders and thus promoting cooperation and efficiency of natural resource management in protected nature territories in Latvia and Lithuania.

Expected project results:

1. Elaborated management tools for various wetland habitats by improving mapping methods and inventing management techniques for various stakeholders, including elaborated nature conservation plans for Pelēču ezera purvs Nature Reserve and Supes purvs Nature Reserve.

2. Elaborated set of integrated methods for assessment of efficiency of management measures supporting further decision-making and selection of management methods, mire habitat management measures implemented in protected nature territories in Latvia and Lithuania.

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Key terms definitions

degraded mire	-	a territory with adversely affected or destroyed natural ecosystem functions and peat formation.
groundwater	-	upper permanent horizon of non-pressurized underground water above the first impermeable layer. Non-pressurised waters, which regimes (table, reserves, composition etc.) are naturally determined mainly by geological structure and climate. Water table can lower due to natural conditions (low precipitation) or human intervention (drainage, water abstraction etc.) that alters the natural hydrological regime.
mire	-	a permanently or seasonally waterlogged area, with characteristic flora and fauna and active peat formation.
peat deposit	-	a territory where geological surveying has been performed and which is recognised as suitable for peat extraction; it includes some damp forest types, drained bogs and peat extraction spots, as well as drained agricultural and forestry lands.
monitoring	-	system of long-term and large-scale observation, control, analysis and forecasting. Prolonged and periodical observations are carried out in the same place (permanent sample plots) with the same method.
vegetation monitoring	-	part of botanical monitoring periodically assessed projective cover of species forming the plant cover and its percentage.
hydrological monitoring	-	hydrological regime observations with elaborated programme and a network of arranged observation plots.

Content

INTRODUCTION

Natural ecological processes are a precondition for conservation of natural diversity and maintaining a quality living environment. Mires are one of the ecosystems endangered by human activity. A distinctive feature of mires are water-logged conditions that cause partial decomposition of dead plants and following peat formation. Natural conditions of mires are significantly affected by hydrological regime changes that causes relatively rapid disappearance of moisture-loving plants thus slowing down or discontinuing peat accumulation and reducing the quality of the mire as a habitat.

In order to facilitate the conservation of mire characteristic conditions, specific management measures — such as elimination of drainage system, removal of trees and shrubs, cutting of reeds etc. — can be taken.

In order to assess the consequences of various factors, incl. natural development, or economic activity, as well as to gather experience, the changes must be examined or monitored, and scenarios of further mire development must be elaborated on a regular basis. So far mire monitoring has been performed by a number of institutions (for example, Latvian State Forest Research Institute “Silava”, establishment “Latvijas dabas fonds” (Latvian Fund for Nature), Institute for Environmental Solutions, limited liability companies) in pursuit of various goals, data have been accumulated sporadically and assessment of management measures and impacts is not sufficient.

Elaboration of a uniform monitoring method is necessary to for the scientifically grounded and comparable (both in terms of time and among objects) assessment of efficiency and impact of natural development of mire habitats or their management measures. However, considering the diversity of mire environment and factors in play, there may be situations where methods recommended in this paper can be fairly substituted or supplemented with others, in such case describing the chosen solutions accurately.

Condition of mire environment can be evaluated from typical flora (vegetation) that is capable of existing only under certain hydrological conditions, therefore, in order to obtain complete information, it is recommended to perform both vegetation and mire water regime (hydrological) monitoring.

Goal of the monitoring is:

1) to accumulate and analyse data on changes in mire habitats (vegetation and water regime);
2) to assess the impact of activity on the quality of mire habitats;
3) to assess efficiency of mire habitat management measure and its compliance with the goal;
4) to warn about adverse changes that indicate at deteriorating condition of mire habitats;

A report on previous mire habitat monitoring in Latvia has been prepared within the framework of study “Monitoring method for mire habitat restoration, management measures and impact assessment”. Examples of applied monitoring methods are analysed by highlighting similarities and differences as well as advantages and possible disadvantages of the methods used. Summary of existing experience has resulted in guidelines for setting up vegetation and hydrological monitoring programmes.

1. GENERAL OVERVIEW ON MIRE MONITORING

1.1. Regulatory framework related to mire habitat monitoring

EU legislation

Council Directive 92/43/EEC of 21 May 1992 **on the conservation of natural habitats and of wild fauna and flora (Habitats Directive)** – aim of the directive is to promote biological diversity, protect natural habitats and wild animals and plants within the territory or European member states.

International conventions

Convention on Biological Diversity signed in Rio de Janeiro on 5 June 1992 aims to conserve biological diversity, ensure sustainable use of living environment, fair and equal consumption of genetic resources, distribution of obtained benefits, including both reasonable access to genetic resources and delivery of relevant technologies, taking into consideration all rights to these resources and technologies, and adequate funding. A need for monitoring is stated in Article 7 of and Annex 1 to this Convention.

Ramsar Convention of 2 February 1971 on Wetlands of International Importance as Waterfowl Habitats aims to protect wetlands of international importance. According to Article 3(1) of the Convention, the contracting parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory. According to Article 3(2), every contracting party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference. Accordingly, this provision serves as the basis for permanent monitoring of wetlands of international importance in Latvia.

LR laws.

Environmental Protection Law (02.11.2006) – Section 17 sets general requirements for a national environmental monitoring. The purpose of environmental monitoring is to specify the state of the environment, to evaluate the tendencies and perspective, to develop environmental policy measures and to evaluate the usefulness and efficiency of previous measures. The law sets sustainable use of resources, competency of national and municipal institutions in environmental protection and use of natural resources, rights of the public to live in good quality habitat, obligations of public in environmental protection and use of natural resources, rights of the public to receive information about environmental issues and to participate in decision-making concerning environmental protection.

Law on Environmental Impact Assessment (30.10.1998) – this law aims to prevent or reduce the negative impact of the implementation of the intended activities of natural persons and legal persons or of a planning document on the environment.

Law on Specially Protected Nature Territories (02.03.1993) – Section 32^1 states that the Nature Conservation Agency organises and co-ordinates monitoring in the protected territories.

Law on the Conservation of Species and Biotopes (05.04.2000). – Section 21, Chapter V, defines species and habitats monitoring and inventory. Purpose of the law is to ensure biological diversity through the conservation of fauna, flora and habitats; to govern the conservation, management and supervision of species and habitats; – to promote the preservation of populations and habitats in accordance with economic and social preconditions, as well as cultural and historic traditions; to govern the procedure for the determination of the specially protected species and habitats; to ensure the performance of the necessary measures in order to maintain the number of populations of wild bird species living in the wild according to their requirements of ecology, science, culture, and taking into account the requirements of economy and recreation to facilitate the approximation of the population of these species to the referred-to level. The law defines competence of State administration and institutions, rights and obligations of landowners and permanent users concerning conservation of species and habitats, as well as a need to carry out the monitoring of species and habitats.

Law On Subterranean Depths (02.05.1996) Clause 6 of Section 14 "Duties of the Users of Subterranean Depths" of the law says that a duty of a user is "to observe the requirements of the laws and regulations governing environmental protection, protection of cultural monuments, land transformation, as well as protection of structures and other objects and to prevent that the use of subterranean depths causes harmful effect to them; the users of the subterranean depths shall not be liable regarding infringements of the laws and regulations committed by previous users".

Regulations of the Cabinet of Ministers

Cabinet Regulation **No. 421** of 05.12.2000 **Regulation of the list of the specially protected biotopes** — when carrying out the monitoring, information must be obtained about distribution, condition and change trends of habitats mentioned in the Regulation.

Article 5 of Cabinet Regulation **No. 264** of 16.03.2010 **General regulation on protection and use of specially protected nature territories**, Nature Conservation Agency classifies information on location of habitats of specially protected species living in the protected area and the location of specially protected habitats, if the disclosure of this information can harm environmental protection. Such information is disseminated only with a written consent by the Nature Conservation Agency.

Cabinet Regulation **No. 267** of 16.03.2010 **Procedures for the Certification of Experts in the Field of Conservation of Species and Biotopes and Supervision of the Activities Thereof**.

Other regulatory documents

National Biological Diversity Programme, accepted by the Cabinet of Ministers in the sitting of 16 May 200, Protocol No. 23 22.§.

Cabinet Decree No. 130 of 26.03.2014 **On Environmental Policy Guidelines 2014-2020.**

Decree No. 67 of Ministry of Environment and Regional Development of 26.02.2015 **On Environmental Monitoring Programme** approves the Environment Monitoring Programme, incl. Section 1.4 "Biodiversity Monitoring Programme"

Guidelines for the improvement of quality of the judgements provided by experts certified in species and habitats protection area in their conclusion within the framework of initial assessment, environmental impact assessment or assessment of impact on Natura 2000 territories, issued by Nature Conservation Agency.

Conditions set for the using of subterranean depths regarding particular object and activity, issued by the State Environmental Service.

Permissions and approvals required to perform monitoring stipulated in laws and regulations

In order to carry out the monitoring in protected nature territory, monitoring programme approved in a written form from the Nature Conservation Agency must be received.

In order to carry out monitoring outside of specially protected nature territories, a consent from the landowner is required.

In order to set up a monitoring system (wells), a licence must be received from the Licensing Department of the State Environmental Service.

1.2. Evaluation of the initial situation

Undisturbed or slightly influenced mires are relatively stable ecosystems, and their vegetation changes slowly in a course of natural development. Significant adverse changes are mostly caused by drainage ditches that impact levels of surface waters and groundwater in larger or smaller area, encourage changes in micro-structures. Drainage usually provides favourable conditions for growth of shrubs and trees. In raised bogs, proportion of heather *Calluna vulgaris* and other dwarf shrubs increase, and cover of *Sphagnum* mosses decreases. In alkaline fens, proportion of *Molinia caerulea* and shrubs increase, and number of habitat-characteristic calcareous species decreases. Result of drainage or other adverse circumstances usually can be observed over a longer period of time. Consequently, peat formation and accumulation are halted or impeded. In area directly influenced by main ditch, a distinctive peat settling and degrading of bog habitat can be observed. Various management measures implemented to reduce or prevent causes of bog degradation, incl. bringing hydrological regime closer to its natural regime, removal of trees and shrubs, are factors showing favourable impact on mire habitat quality.

Mire habitat monitoring is carried out in the following cases:

1. Scientific research;
2. Monitoring of Natura 2000 sites;
3. Efficiency assessment of management measures;
4. Assessment of management impact on area adjacent to mire, incl. to meet the requirements set forth in Regulations concerning the use of subterranean depths;
5. Other reasons (for example, personal interest).

When collecting information about mire monitoring in Latvia, two important factors must be highlighted; (1) measurements made in the past are not digitalised therefore they cannot be found in internet resources or databases; (2) no uniform national level monitoring methodology has been developed. Therefore, results of monitoring performed in mires are not comparable.

Most often mire monitoring is carried out by certified mire habitat experts; hydrological monitoring is carried out by professionals with relevant experience. Existing, recently started and commenced monitoring programs are currently regarded as too short-term to completely assess the results obtained.

2. MIRE VEGETATION MONITORING

2.1. Monitoring for the purpose of scientific research

Collecting and processing of long-term data on environmental conditions play an important role in mire research. Historically, interest about mires was driven by their use — for agriculture or forestry, or as a source of peat resources. This determined the further development of mire and peat research methods. Systematic research of Latvian mires was started in 1926 when the Mire and Peat Research Laboratory was established in the University of Latvia. Under the lead of Pēteris Nomals (1876-1949) active mire research was continued until the other half of the 20th century, as long as peat remained an important source of energy. Research of mire flora was launched by Marija Galeniece (1891-1984), who used pollen analysis in researching of peat and mire environmental conditions. This allowed tracing climate changes in the territory of Latvia in post-glacial period. Nowadays the interest on mires as ecosystems, their functions and role in the context of biodiversity conservation and climate changes is high. As the need for peat as a raw material was rapidly losing its position in the renewed Republic of Latvia and as Latvia accessed the European Union, mire habitats have become a subject of research, solutions for mire conservation and management are being sought.

Studies that meet the principles of scientifically grounded long-term data collection or monitoring, that have been carried out with a single method in the same sample plots in mid-20th century were started and in certain cases are being continued in some protected nature areas, for example, Teiči Nature Reserve and Ķemeri National Park, Slītere National Park. A long-lasting research programme in several mire sites is implemented by "Silava". In 1990, six permanent sample plots were established in Teiči mire complex: three of them in raised bog, two in transition mire and one in fen (additional information in Chapter 2.1); a repeated survey was performed in 1995. Observation results were reported in an article "Dynamics of mire vegetation in Teiči Reserve" (Bambe, 1998). A monitoring "Observations of vegetation dynamics in burned raised bog" was also launched. In 1964, vegetation monitoring plots in mire were set up in Teiči Mire, mainly to study diversity of moss species, but unfortunately no regular data have been obtained so far. The accumulated data are available in personal archive of B. Bambe. When implementing rewetting measures in Teiči Mire, dich dams were constructed, monitoring of management measures was started by creating vegetation sample plots (Kreile, Namatēva, 2007).

Currently available science funding and principles of its distribution do not favour the research of mire habitats.

2.2. Natura 2000 monitoring in mire habitats

Laws and regulations of EU and Latvia set an obligation not to worsen the state of environment. In Latvia Biodiversity monitoring sub-programme is carried out to ensure regular assessment of quality of habitats in Natura 2000 sites.

Monitoring methods of *Natura 2000* sites in Latvia were elaborated in 2007 by SIA ELLE according to a procurement of LVĢMC. In 2013 monitoring methods were updated regarding objects, including mires, that must be subject to monitoring. Monitoring objects are selected randomly, and monitoring method is based on assessment of mire habitats' structure and vegetation in a transect by filling out a relevant surveying form on mire habitat. Environmental Monitoring Programme 2015–2020, in a section of Biodiversity Monitoring Programme, sets a need for monitoring in Natura 2000 sites and background monitoring in mires every six years. Monitoring of Natura 2000 sites must be carried out by the Nature

Conservation Agency. It is planned to change the methods of Natura 2000 monitoring programme, while background monitoring programme has not been implemented yet.

Currently information about the state of Natura 2000 habitats is being obtained within the framework of EU Cohesion Fund's project "Preconditions for better biodiversity preservation and ecosystem protection in Latvia" or so-called "Nature Census".

2.3. Assessment of efficiency of mire and peatland management measures

The purpose of mire habitat management is to improve their quality; therefore, monitoring is aimed at assessing the efficiency of mire management measures.
These measures are mainly related to hydrological regime stabilization. Aim of the monitoring is to assess how the management measures influence the areas to be restored, and to evaluate if the current measures are sufficient.

As Latvia accessed the European Union, it could start participating in projects such as LIFE, INTERREG and other programmes that focus on promoting conservation of biological diversity and that gives an opportunity to implement practical management measures, incl. mire habitat improvement. In several Natura 2000 sites ditches having an adverse impact on mire habitats were blocked (Teiči Nature Reserve in Teiči Mire complex, Cena Mire in Cenas purvs Nature Reserve, Lauga Mire in Augstrozes purvs Nature Reserve) or excessive tree and shrub vegetation was removed (Rampa Mire, Ādaži Protected Landscape Area, Pelēči Mire in Pelēči ezera purvs Nature Reserve). Monitoring is launched in the initial stage of the project, but usually is not continued after the end of the project, because permanent funding for this purpose is not provided in Latvia.

Mire habitats have been managed, for example, in the following projects:

- LIFE 08NAT/LV/000449 "Restoration of Raised Bog Habitats in the Especially Protected Nature Areas of Latvia" ("Raised bogs"), period of implementation – 2010-2013. Dams are constructed on drainage ditches in Rožu Mire (Sala municipality), 95 peat dams have been constructed, changes in hydrological regime are expected to affect 235 ha large area. 25 plots in 5 transects have been arranged for monitoring purposes.
- LIFE 12NAT/LV/000509 "Improving of the conservation status of specially protected bird species in Natura 2000 site „Adazi"" ("Birds in Ādaži");
- LIFE13 NAT/LV/000578 "Conservation and management of priority wetland habitats in Latvia";
- LIFE14 CCM/LV/001103 "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore).

2.4. Assessment of impact of management type carried out in mire adjacent area

Use of the peat as a fuel and in agriculture had an important role in Latvian economy until the 1990s. The largest wetlands were the most suitable for industrial peat extraction. By increasing the number of protected nature territories and creating new protected areas in mires, rare species or habitats important for biological diversity were found in many of the peatlands. These localities or their parts became protected nature territories or areas directly adjacent to them. When network of Natura 2000 territories was established, restrictions concerning environmental impact became binding on activities in peat deposits.

Peat extraction is not technologically feasible without drainage. Also, adjacent mires are affected by contour ditches. Management of mire adjacent areas for extracting useful resources or using them for agriculture purposes usually worsen the state of mire habitats, because virtually they always involve drainage of the area.

In order to launch an activity or expand areas of peat extraction according to the license (in other similar peatland management measures) and harmonising technical tasks and conditions of use of subterranean depths in the State Environmental Service for the purpose of assessing potential impact, a company involved is obliged to carry out vegetation and hydrological monitoring in Nature 2000 territories adjacent to peat extraction sites at own expense. Licensing requirements envisage regular hydrological regime and botanical monitoring to detect possible changes in determined buffer zone or adjacent areas. Setting up of hydrological regime and botanical monitoring and conditions of their performance must be authorized by the Nature Conservation Agency.

2.5. Comparison of vegetation monitoring methods

When analysing the available monitoring programmes (Annex 1) it can be concluded that monitoring is generally carried out according to equal principles: inventory of species and assessment of cover in a sample plot of certain size; plots are arranged in groups or transects. Locations of setting up the plots are chosen, based on a parameter to be evaluated — impact of management measures, ditches (Annex 4).

Teiči Wetland vegetation monitoring was launched for the purpose of scientific research of processes in mire. Vegetation dynamics was studied in a number of plots (Bambe, 1998). 20 vegetation inventory sample plots of 1m² of size were arranged in a 100m long transect with 5m distance in between. The sample plots were located randomly, depending on the location of hummocks and hollows. In total, 20 sample plots were inventoried. Observations were recorded in a notebook, in simple tables.

Habitat restoration works are planned in Rampa Mire within LIFE project LIFE12NAT/LV/000509 “Improving of the conservation status of specially protected bird species in Natura 2000 site "Adazi". Description of monitoring method (Auniņš, 2014) states that monitoring must be performed both in territory of activity and in control area. Sample plots of 100 m² (10x10 m) in size must be established, where plant species and their cover in percentage must be inventoried. Cover of species must be evaluated separately at the overstory layer (h>2m), shrub layer (h=0,30 – 2 m), herbaceous layer and moss layer. Field data form is not included in this instruction.

“Botanical monitoring to determine potential changes in mire habitats in buffer zone of peat extraction site in Aizkraukle (Aklais) Mire” is implemented in Aizkraukle Mire. Method was elaborated by habitat expert Agnese Priede (Priede, 2014) according to Conditions on use of subterranean depths issued on 19 May 2011 by the State Environmental Service, licensee — SIA “Kūdras enerģija”. In total, 30 plots were arranged in 6 transects.

Peat extractor SIA Klasmann-Deilmann Latvia at company's own initiative started vegetation monitoring in *Rāķa Mire* in 2017, in *Lielais Mire* and *Ozolmuižas (Ozolu)* Mire in 2018. Monitoring territory in Ozolu Mire is included in North Vidzeme Biosphere Reserve, situated in Kocēni municipality, Dikļi rural territory. Part of mire is actively used for peat extraction. Sample plots are located in different distances from peat extraction territory, in sites with the highest water table, assuming that they will illustrate water fluctuations best. Size of sample plots – 8 x 8m. In order to prevent trampling, this plot is divided into 4 smaller plots in the corners, in 2 m² area each. It is planned to repeat the monitoring every 5 years. Aim of monitoring — to evaluate the actual vegetation condition to notice changes as soon as possible.

Common elements in monitoring methods:

- Inventory of plant species and assessment of cover in %, generally referring to principles of Braun-Blanquet (Braun-Blanquet, 1932);
- Recommended and implemented monitoring time – from mid-June until the end of August;
- Data are stored in Excel file;

Distinctive elements in monitoring methods:

- Number and arrangement of sample plots — in groups, rows, various distance from each other;
- Size: 1 m², 10 m²; plots are usually grouped inside a larger plot (10 x 10 m, 8 x 8 m or 5 x 5 m);
- Shape: circle or square. Most commonly used size and shape of vegetation inventory plot is 1 m² square. Plot is marked by driving a peg into the ground in a certain corner or all four corners. Experience of several experts encourages using round plots, 2m or 1.5m in radius; the plot's centre is marked with a peg. Mire vegetation is relatively poor and homogeneous concerning species, while micro-terrain conditions are heterogeneous. Sample plot with 1 m² area may insufficiently illustrate the natural vegetation. In this case, a larger number of plots is required. At the same time, it must be noted that plots with larger areas are harder to describe or the subjectivity level here is potentially higher. Plots of larger size have a risk of trampling.
- The planned frequency of monitoring: every 6 years (Natura 2000 site monitoring); vegetation monitoring in LIFE projects concerning mires is planned every year, in Dzelve-Kroņi Mire — every 5th year;
- Additional parameters: at choice of contracting entity and possibilities of persons performing monitoring, additional parameters may include: pH value of soil water measured and the relative values estimated using Ellenberg indicator scales;
- Overstory layer in Rampa Mire monitoring is defined as h>2m, while shrub layer h=0,30-2 m.

Recommendations:

1) Exclude the determination of vitality of trees, shrubs, dwarf shrubs, because the sufficient visual evaluation of vitality of trees and shrubs in complicated growth conditions is not possible;
2) In case of management measures related to direct impact on hydrological regime (filling up or blocking of ditches), hydrological monitoring is not necessary;

Main factors influencing the process of monitoring:

1) Expert subjectivity;
2) Choice of a location of sample site suitable for monitoring goal;
3) Repeated finding of sample plot.

2.6. Description of vegetation monitoring method (monitoring programme)

Vegetation monitoring method must correspond to the aim of monitoring and specifics of object or measure to be monitored.

2.6.1. Aim of monitoring

Aim of particular monitoring must be defined. If monitoring is performed to evaluate changes after implementation of certain activity, potentially expected (planned) results of activity impact must be specified — for example, what is the size of area possibly affected by drainage. The monitoring must describe all area of possible impact.

2.6.2. General assessment of situation

Before starting the monitoring, it is necessary to survey the territory by analysing all available literature and visiting the site. In order to assess the general situation in Natura 2000 territory, a description of vegetation is necessary (Annex 1) according to principles of Natura 2000 monitoring method to ensure the data comparability and succession to an extent possible. All monitoring data must be stored in nature data management system "Ozols".

2.6.3. Size and shape of sample plot

Round plots with a radius 2m are established. Plot centres are marked in a map of proper scale and on potentially lasting natural objects, such as trees. It is advisable to mark the plot centres with pegs. It is recommended to use 1.5m long wood or bamboo pegs and drive them sufficiently deep to keep them stable and mark their ends with a paint suitable for outdoor applications. Two crossed measuring tapes visualising the area inside a circle are used to determine the plot area (Figure 1).

Fig. 1. Vegetation sample plot in Pelēču ezera purvs Nature Reserve (photo: A. Priede).

2.6.4. Arrangement of sample plots

Sampling locations are selected depending on specifics of the object and access options to the observation points and plots in a long-term (for example, it is not reasonable to arrange plots in places that can overflow after the mire restoration).

Sample plot locations in one habitat must be uniform and as homogeneous as possible. If conditions of micro-terrain, humidity and vegetation are varying, number of sample plots must be increased so that the data set is representative.

Sample plots must be arranged in one or several transects that characterise typical conditions and landscape of mire (Annexes 5 and 6).

If also hydrological monitoring is carried out, vegetation monitoring sample plots are arranged in parallel to transect of hydrological monitoring, but no closer than 10m to avoid trampling that can occur if hydrological monitoring observation points are visited often.

When evaluating the *impact of activity,* transect of plots must cross the area of monitored impact, including also potentially intact area. *Control* (reference) situation must be reflected in 10% of total number of sample plots.

If ditch impact is assessed, transects must be arranged perpendicular to the ditch. Impact of ditches in a long-term perspective may be wider. The directions of groundwater flow, mire water flow and ditches must be taken into account.

In habitats that usually cover small areas — 7140* *Transition mires and quaking bogs*, 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae, 7230 *Alkaline fens* – sample plots are arranged in a transect from edge towards the centre to embrace a possibly larger territory in a certain distance.

Sample plots must be arranged one by one along the entire transect. In some cases, it may be useful to arrange plots in groups. Then, expert justifies such choice and explains it in a relevant method.

Coordinates of the plots centres are determined and recorded in LKS92 system.

Every plot is given a unique ID code. The code consists of two capital letters, plot number and last two digits of monitoring year: for example, Ķemeru tīrelis ĶT01_18, Cenas tīrelis CT01_19.

Photos of plots must be taken. Photo materials must show the general views of places to be monitored, typical vegetation, structures, micro-terrain, and changes in these parameters. In each surveying, photos of the plots are taken from the same viewpoint, if possible. Informative badge/plate with capture date and number of plot must be seen in the photo. Photo files are named according to plot's ID code and shooting day, for example, ĶT01_20_08_19. In repeated surveying of the plots, it is advisable to bring photos from previous surveying.

Considering the accuracy of tools for determining coordinates, possible loosing of central pegs of the plots, fading paint on trees and change of the person performing monitoring, one must take into consideration that place of the plot may not be found precisely. In such case one must choose the sampling site that is closer in terms of coordinates and most suitable in terms of photos. The centre of the new plot must be marked according to the method description. Slight change in plots’ arrangement to evaluate dynamics of mire if conditions of the place are generally homogeneous is considered as insignificant.

2.6.5. Minimal and optimal number of plots, time and frequency of monitoring

Number of plots

Minimum number of plots in mire habitats for the assessment of certain impact (ditch, logging) is 20. The only exceptions are mires smaller than 1 ha where the number of plots can be lower. If an expert decides that a smaller number of plots is sufficient, it must be explained in a method description.

Optimum number of plots is 30. In large heterogeneous territories with complex impacts, the number of plots for assessment of those impacts may be higher. If an expert decides that a larger number of plots is needed, it must be explained in a method description.

Time of monitoring

Monitoring must be carried out during active vegetation season, on the same time period. Recommended period in fens and transition mires – end of June – end of July;
in raised bogs – June – end of September.

<u>*Frequency of monitoring*</u>

Changes in mire habitat progress rather slowly, therefore the first repeated monitoring must be carried out in the 3rd year. Afterwards, monitoring in habitat types 7110* and 7120 is carried out every 5 years. If for any reason the monitoring is necessary more frequently, the expert must justify this when preparing a method for the particular monitoring.

Monitoring in habitat types 7140* *Transition mires and quaking bogs*, 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae, 7230 *Alkaline fens* must be carried out every two years.

If monitoring is carried out to assess impact from the activity that has already occurred and which impact is expected to be rather rapid (for example: construction of dams, blocking of ditches, removal of trees and shrubs, mowing in fen), the monitoring must be performed at least every two years.

2.6.6. Detailed description of monitoring methods

Habitat monitoring is basically based on recording of number of species and cover of plants in equally sized plots. All species found in the plots are registered as well as their cover. Only parts of living plants are assessed are expressed in percentage (i.e. cover does not include an area covered by dead plants and their parts; presence of dead plants can be recorded separately).

Habitat is described in layers:

1. Moss and lichen layer (E0);
2. Herbaceous layer (E1);
3. Shrub layer (50cm – 5m) (E2);
4. Dwarf shrub layer (Ezk)
5. Overstory (trees above 5m) (E3).

Herbaceous layer consists of herbaceous plants and dwarf shrubs regardless of their height (for example, *Ledum palustre*, *Vaccinium uliginosum*). Herbaceous layer includes also trees and shrubs up to 0.5m in height. Total cover of the herbaceous layer is made of plants overlapping due to the height difference and arrangement of leaves. Summing up the covers separately assessed for each species, the final value (total cover) may not exceed 120%.

In habitat types 7140* *Transition mires and quaking bogs*, 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae, 7230 *Alkaline fens* dwarf shrub layer Ezk are described separately, including also species of trees and shrubs that never reach the overstory layer: *Betula humilis, Betula nana*, *Salix rosmarinifolia*, *Salix lapponum*, *Myrica gale*. Birch and pine seedlings are included in inventory in each plot.

Withered trees, shrubs or dwarf shrubs are assessed separately.

In each plot, area covered by litter and structures (tall hummocks, low hummocks, even surface, hollows, open water, bare peat) must be assessed and their cover in percentage registered.

Additional parameters can be included according to the monitoring task — for example, assessment of the burnt areas in burnt mires.

If the species cannot be identified on the spot, herbarium or samples must be taken and determined in a lab or in consultations with professionals. Mosses and lichens are accounted only where if grow on the soil; inventory does not involve moss on stems of living or dead trees and other objects such as stones.

2.6.7. Pre-requisites of monitoring

Weather:
monitoring must be carried out in suitable weather conditions (preferably — without precipitations and snow cover).

Necessary equipment:

- GPS receiver or equivalent device;
- At expert's choice – suitable cartographic material;
- Measuring tape (5m or longer, if distance between the plots is measured with a measuring tape);
- Pegs (1-1.5m) for marking centres of sample plots;
- Camera or smart device for taking photos;
- Notebook, material for written records;
- Writing tools, incl. waterproof marker.
- Bags for collecting unidentified specimens;
- Paint suitable for external applications to mark plot centres or indicative trees

Qualification of person carrying out monitoring:

- Monitoring is carried out by accordingly qualified person who recognises plant species and who is experienced in determination of EU protected habitats (Auniņš, 2013);
- If monitoring is necessary for the assessment of impact of planned or implemented mire restoration or management, or monitoring is necessary to meet the requirements listed in Conditions on use of subterranean depths, or for the assessment of initial impact, environmental impact assessment or impact on Natura 2000 territory, it is performed by certified habitat expert (procedure of certification of experts is stipulated in Cabinet Regulation No. 267 of 16.03.2010 “Procedures for Certification of Experts in the Field of Conservation of Species and Biotopes and Supervision of the Activities Thereof”).

2.6.8. Habitat observation field data form

Field data forms are attached to Annexes 2 and 3. Later, data are transferred to .xls databases, processed and analysed.

Cover of species in sample plot is recorded in percentage, the least value being “0.1”, if the cover is less than 1%.

2.6.9. Data processing and interpretation of results

Monitoring results – description of plots and report prepared by the person carrying out the monitoring (expert) is prepared and submitted according to tasks set by the contracting entity. A certified habitat expert submits the report to the Nature Conservation Agency (Vadlīnijas sugu un biotopu…) within one month unless stated otherwise in the contract.

Data are stored in .xls database, by supplementing monitoring data set in each replication. Data are structured by places and years of monitoring – a separate Excel file for each mire, data on each monitoring year are stored in a separate sheet.

Monitoring data must be analysed with statistic data processing methods suitable for the monitoring goa. Parameters to be analysed: number of species in the plot, presence of species (5), numerical value of cover of the species (%). Ecological scale of Ellenberg (Ellenberg, 1979) can be used to characterise ecological conditions (please see examples in Table 1). Statistical significance of monitored parameter is assessed. Example of monitoring data processing – Figure 2.

When interpreting data, one must take into account all available information and data about general state of the habitat in country, changes in climatic and hydrological conditions. When comparing various mires (monitoring results), mire types and their geographical location must also be taken into account. For the assessment of mire habitat, characteristics of respective geobotanic region must be considered. Data are analysed successively by years and compared for the identifying the major changes or fluctuations according to the aim of the measure or monitoring.

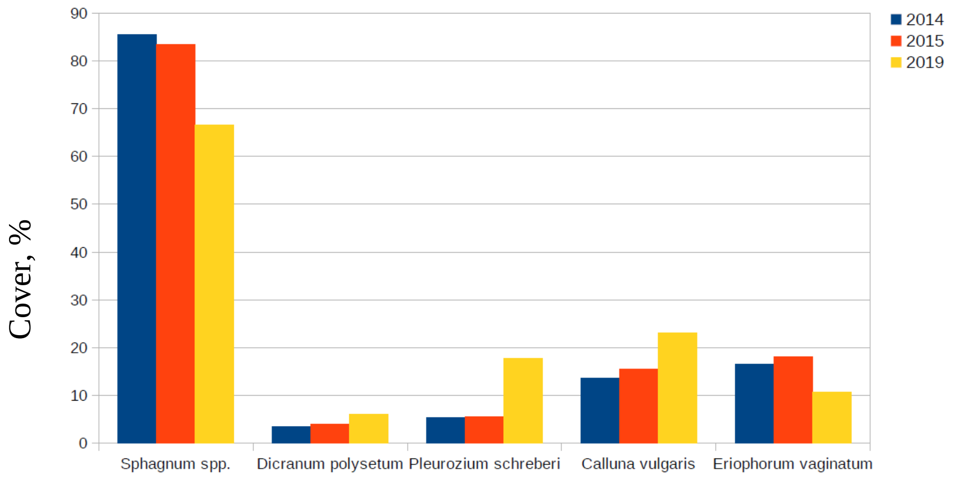


Figure 2. Results of monitoring data processing (Priede, 2019).

Main parameters to be analysed in habitat types 7110* and 7120 – proportion of dwarf shrubs and *Sphagnum* as well as proportion of bare peat (without plants). *Sphagnum* mosses are the main builder of peat, and the presence of *Sphagnum* carpet (sufficient *Sphagnum* cover, regardless of predominant species) potentially indicates on peat accumulation and on sufficient moisture. An increase in proportion of *Calluna vulgaris* and other dwarf shrubs potentially indicate on hydrological regime changes, even though it must be remembered that *Calluna vulgaris* dominance can be characteristic in undisturbed raised bog.

So far it is not been sufficiently clear at which indicative parameters we can conclude that there are adverse changes in vegetation or hydrological regime, and what further steps should be taken.

Reduction of *Sphagnum* cover below 50%, regardless of the diversity of *Sphagnums* or dominant species, can be used as indicative parameter in habitat type 7110*. Reduction of *Sphagnum* cover below 30% indicates on adverse trend in habitat type 7120.

Indicative species (moisture change indicators)

Sphagnum — a genus of water-loving mosses. Changes in *Sphagnum* cover indicate on moisture regime changes. *Sphagnum* is an important part of acrotelm of active raised bog that ensures peat accumulation. Proportion of *Sphagnum* cover above 50% indicates a favourable condition of mire habitat. When performing monitoring, minimum requirement is the determination of *Sphagnum* total cover in the plot without identifying species. Optimum requirements — to identify species of *Sphagnum* hummocks (S. *magellanicum, S. fuscum), their cover,* and cover of hollow species – *S. angustifolium, S. tenellum).*

Common heather ***Calluna vulgaris*** – typical species in raised bog. Significant changes in its cover indicate on hydrological regime changes. Additionally, it must be taken into account that withering of heathers can be caused by prolonged drought, cold, snowless winters. Dense, wide-spread heather growths do not indicate on favourable condition of mire habitat.

White beak-sedge ***Rhynchospora alba*** – is distinctive moisture-loving species in even micro-terrain and in hollows. Their dominance indicates on favourable conditions of mire habitat. If there are just some scattered specimens between the hummocks and in hollows, they do not have any indicative weight.

Establishment of common reed ***Phragmites australis*** and purple moor-grass ***Molinia caerulea*** is regarded as an adverse trend.

Changes in a number of mire characteristic species by years cannot be interpreted with certainty as improvement of worsening of habitat. In all cases, introduction of mire uncharacteristic species is considered as unfavourable.

Adverse impact indicators whose attainment requires to assess possible actions eliminate adverse impact:

- In mire adjacent areas which have been assessed as corresponding to habitat type 7110* *Active raised bogs* before the implementation of Activity – reduction of habitat quality, cover of *Calluna vulgaris* and other dwarf shrubs higher than 50%.
- In mire adjacent areas which have been evaluated as habitat type 7120 *Degraded raised bogs still capable of natural regeneration – Sphagnum* cover is lover than 30% in more than one half of area.
- Area covered by protected habitat types (except 7120 *Degraded raised bogs still capable of natural regeneration*) is reduced due to Activity
- Abundance of calcareous species decreases in alkaline fen habitats;
- *Phragmites australis*, *Molinia caerulea* are introducing in areas where they were not observed earlier, or their proportion grows significantly.

Plan of measures if adverse effects are observed during the implementation of planned activity

There is no sufficient experience in Latvia on the elimination of adverse effects which are identified by monitoring. Often, monitoring is started after the prolonged influence of adverse factor in mire, or is started after the elimination of adverse effect. Therefore, reliable information on the reference situation is often missing.

If during an inventory the expert observes a trend of worsening situation or significant adverse impact on protected habitats, he or she must immediately submit a written report for the Nature Conservation Agency and Company or entity/person that proposed the monitoring.

2.6.10. Approbation of mire habitat vegetation monitoring method in Pelēču ezera purvs Nature Reserve.

When elaborating nature management plan for Pelēču ezera purvs Nature Reserve, a necessity to remove trees and shrubs in habitat type 7140 *Transition mires and quaking bogs* at the coast of Pelēči Lake was established.

Before the activity, vegetation monitoring was carried out to describe the initial situation.

Vegetation was inventoried in 20 sample plots (Fig. 2, Annex 4). 20m distance between sample plot centres was measured with a measuring tape, coordinates of plot centres were written down.

Centres of plots were marked with 1.5m long bamboo peg, tip of which was painted with red colour.

Plot shape — round; plot size — 2m in radius.

Vegetation was inventoried at overstory, shrub, dwarf shrub, herbaceous and moss layers. Observed plant species were identified and proportion of their cover was assessed in % (Annex 3).

Photos of the plots were taken (example: Fig. 3, 4).

Figure 3. Plot 5 (photo: A. Priede).

Figure 4. Plot 17 (photo: A. Priede).

3. GUIDELINES FOR HYDROLOGICAL MONITORING IN MIRES

3.1. Evaluation of initial situation

Hydrological regime, including groundwater table and its fluctuations, is among the key factors in mire research, evaluation and wetland restoration. Even though mires cover a relatively large area in Latvia, the Environmental Monitoring Programme, approved by Latvian Environment, Geology and Meteorology Centre, mainly focuses on monitoring in 4 large river basins according to the Water Framework Directive, and wetland research is not directly highlighted. The mentioned programme includes monitoring of surface water, subsurface water and drinking water, as well as assessment of their quality. Wetlands are not separately covered in this monitoring programme. However, it must be noted that specific hydrological conditions develop in mires and they are different in a cross-section, because they largely depend on peat filtration properties that are reducing considerably as the peat compacts.

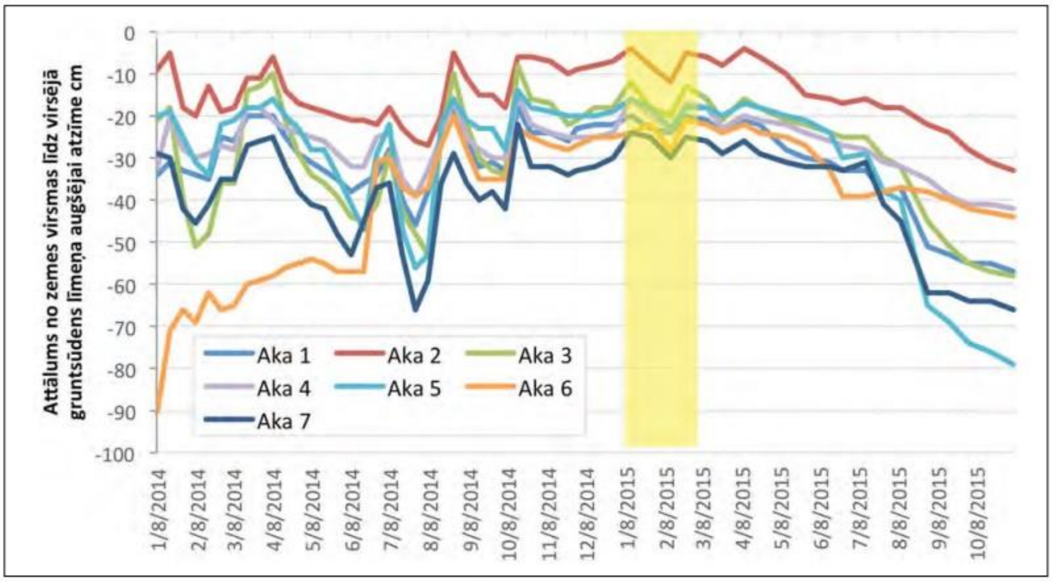
Water regime measurements are carried out and have occurred earlier in wetlands, but these data are rarely publicly available. Often, they are related to wetland restoration projects implemented in Latvia. By elaborating monitoring programmes, one must consider that tasks defining the series of such data lacking description of tasks and goals can provide insufficient or even erroneous information and understanding

At the same time there might be specific observation goals that are relevant only to performer of monitoring, or vice versa – due to complexity of situation, data or their description are useful only for certain circle of professionals. For the comparison and assessment of possible changes in mires, it would be advisable to include regular mire hydrological monitoring in undisturbed (natural) mire complexes in national monitoring programme, as besides the assessment of human activities, it might be necessary to assess the reaction of wetlands to climate change.

Globally and in Latvia, wetlands have been studied and main conclusions have been published in scientific and popular science periodicals. Often, research results can be attributed to the processes in mires of the given climate zone. This set of conclusions and understanding allows the elaboration of optimal monitoring programme and interpretation of results. At the same time, it must be noted that water table measurement data in mires are sparse and such monitoring is not included in national level programme. Water level fluctuations are not distinct in undisturbed raised bogs and they can be compared with other bogs. Therefore, measurements of water table are more important in affected, degraded bogs and in some cases in territories where activities are planned with a potential impact on natural water table.

In general, images of individual results without the data rows are available. They are available from wetland restoration projects in Latvia and their reports (Aizkraukle, Melnais, Rožu, Melnais Lake Mire, Zaļais Mire, Gulbjusalas Mires). Parallelly, monitoring is being carried out or was performed earlier, for example, in Nida Mire, Kroņu-Dzelves Mire, Rampa Mire, Teiči Mire, Ķemeri Mires, as well as has been carried out in individual territories before the transformation. However, these results are not widely available or can be obtained only from monitoring performers.

Water table measurements in mires most often have been carried out during the implementation of LIFE+ projects, and mainly to achieve project-specific goals within a certain territory and under specific conditions (Figure 5).



13. attēls. Virsējā gruntsūdens līmeņa mērījumi hidroloģiskā monitoringa akās pirms un pēc projektā veikto pasākumu īstenošanas Gulbjusalas purva purvainos mežos. Ar dzelteno krāsu iezīmēts laika periods, kad notika grāvju aizbēršana un aizsprostu būvniecība.

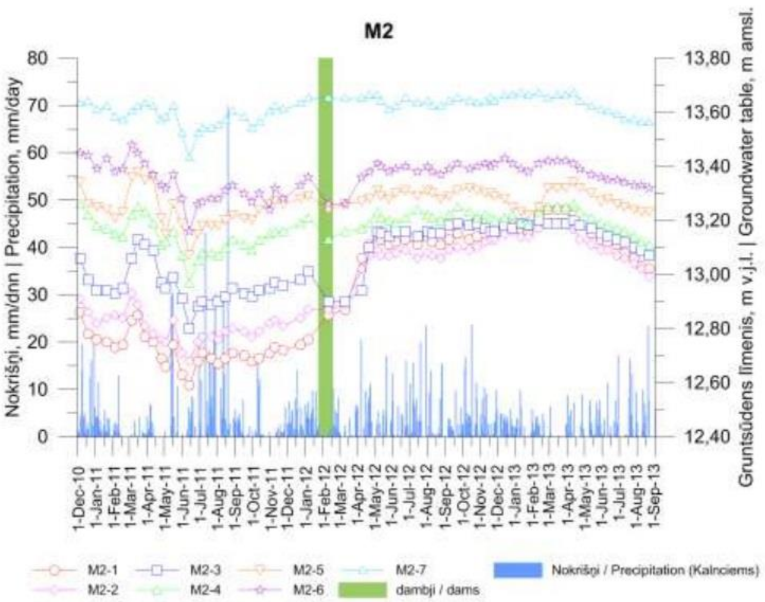


Figure 5 - Groundwater table in profile M2 near deep, draining ditch in Melnais Lake Mire

Figure 5. Examples from results available in project reports attributable to wetland monitoring results.

Results obtained from a particular monitoring depend not only on goals, but also on the wetland – its type, level of degradation/quality. Without referring to very specific circumstances, most of the run-off in raised bogs – up to 99% – takes place in the upper active layer of 20-30cm in thickness; some authors mention even 0.4-0.9 m thick layer (Romanov, 1968), consisting of poorly decomposed raised bog peat with plant residues and with filtration channels of increased velocity. Hydraulic connection of mire water with surrounding surface water bodies in natural conditions is encumbered. It proves the known fact that a natural raised bog is not directly involved in water balance (including level of groundwater table) of the surrounding territory. Peat layer absorbs most atmospheric precipitations, mainly for evaporation and transpiration (evaporation from plants) rather than for water exchange with adjacent water objects. The situation is changing dramatically if drainage system is established in the bog as it facilitates water run-off from the active layer. Water flowing in the active raised bog peat layer is surface water and groundwater at the same time, i.e. surface water and groundwater run-off takes place simultaneously in this layer, leading to a situation where "groundwater" table in the peat layer in an undisturbed state of bog is only slightly below the ground's surface, whereas that level is much lower in bogs affected by drainage (Figure 6). It depends on mire type and corresponding differences in their structure and main sources of water (Figure 7), amount of precipitation, air temperature, season, specifics of the drainage system, geological and hydrogeological conditions in the territory. Extent of drainage achieved with ditches in the raised bog can differ depending on depth and orientation of the ditch towards the dome. Hydrologists and peat extraction professionals engaged in drainage of wetlands for peat extraction have the experience of efficient drainage. Recommendations for raised bog drainage for this purpose involves ditch formation in several stages. The first one is the main ditch, 1.1m in depth, followed by field ditches (drains) up to 1m in depth (Šnore, 2013). Distance between field ditches usually varies between 20 and 25m, ensuring groundwater filtration towards the ditches and water table lowering in general, forming groundwater drawdown curve (Figure 7) with the highest water table between the ditches in the middle of the bog area. As the water table drops, peat layer compresses and ditches become filled up, therefore they are dredged and cleaned in certain time intervals. In further stages, depending on conditions in particular location, other ditches are either dredged or cleaned to efficiently channel water from this territory. These activities indicate on water-retaining ability of raised bogs and relatively long-lasting drainage before starting of peat extraction. In fen, the distance between field ditches may be increased to 40m, as these mires are easier to drain (there can be exceptions depending on conditions in a particular mire), as well as potential change of any water table can have a wider (further reaching) impact. For example, drainage effect by ditches is much higher in tropical mires in south-east Asia. Apart from peatlands' differences depending on their hydraulics, relevant factors are also their location in terrain, and depending on mire type, also subsurface water regime, amount of precipitation, habitat type, and vegetation in the region.

Water saturation differences in bog peat (bog water, groundwater) are characterised by drawdown curves, differences of which are clearly demonstrated in modelling results by O. Aleksāns (Figure 9). Graphs illustrate situation in Northern Bogs (Ziemeļu purvi), allowing the quick determination of approximate lowering of water table in the peat layer in perpendicular to the ditch at any point in a distance of up to 100 metres from that ditch (with ditch depth from 0.2 to 3m). Similar trends can be observed also in other raised bogs, with possible changes as the affecting factors and their intensity vary. Similar data on long-term impact of drainage ditches on adjacent mire are obtained also in Zaļais Mire (Purmalis et al., 2016), where statistically assessed distance of drainage impact from the quarry (with lower water level compared to bog) to relatively unaffected site reaches 122m. In fens, these trends and distances from affected areas may differ, moreover, there might be certain differences between raised bogs and transition mires both in terms of water replenishment and amount and types of precipitations, as well as terrain and other important factors.

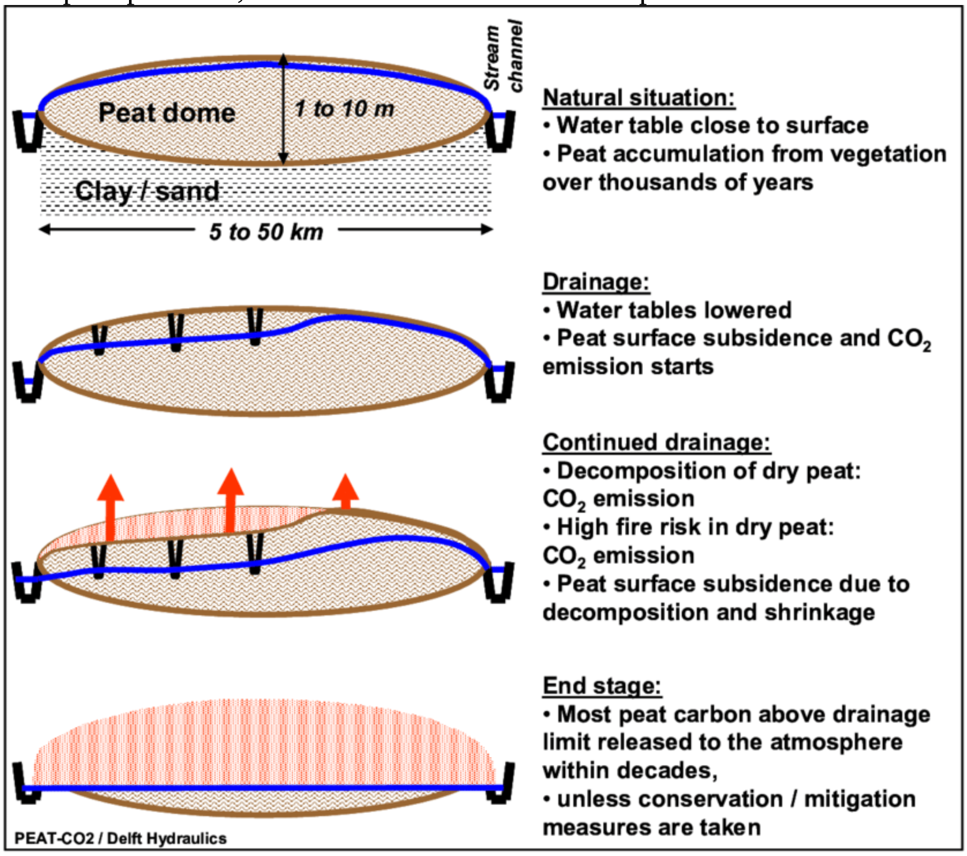


Figure 6. Predominant processes during bog drainage.

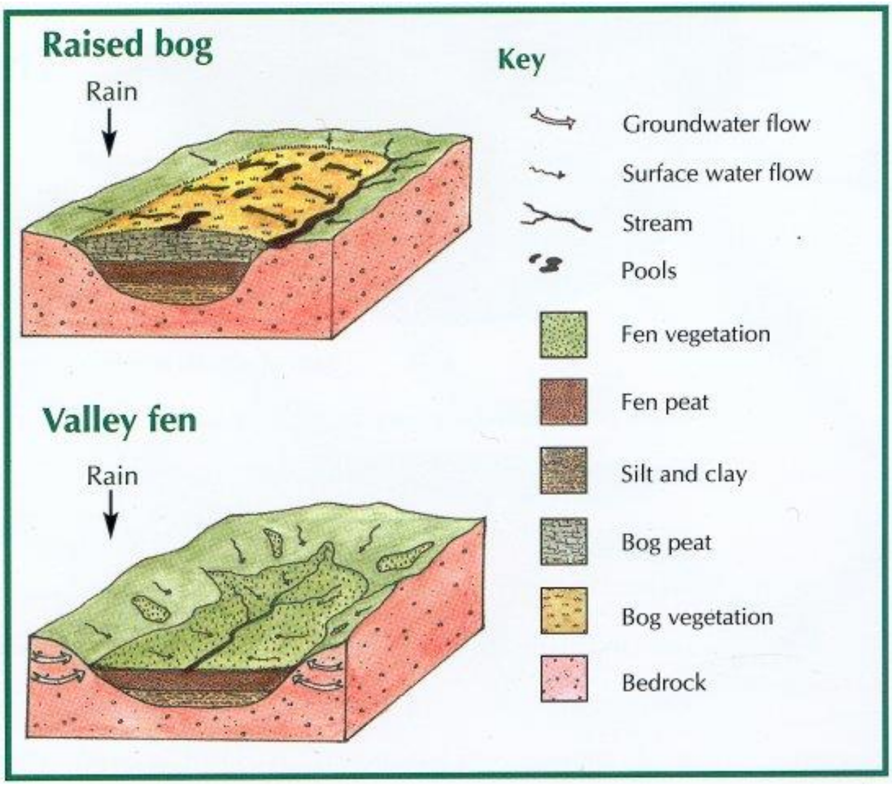


Figure 7. Schematic illustration of differing mire types (raised bog in upper part of illustration and typical fen in the lower part of illustration).

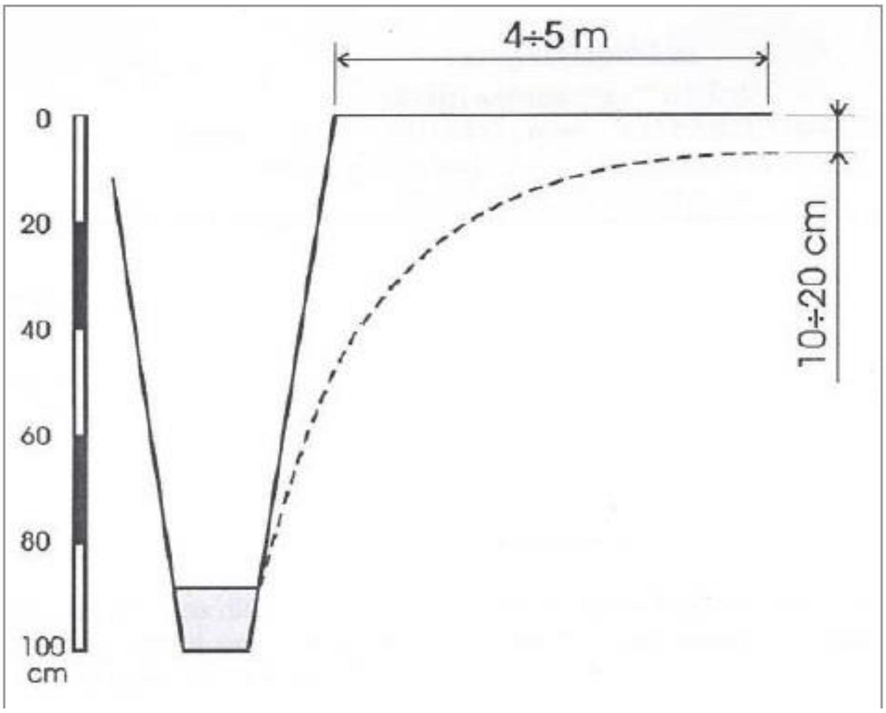


Figure 8. Typical drawdown curve of water table in raised bogs at a drainage ditch (acc. to prof. J. Valters).

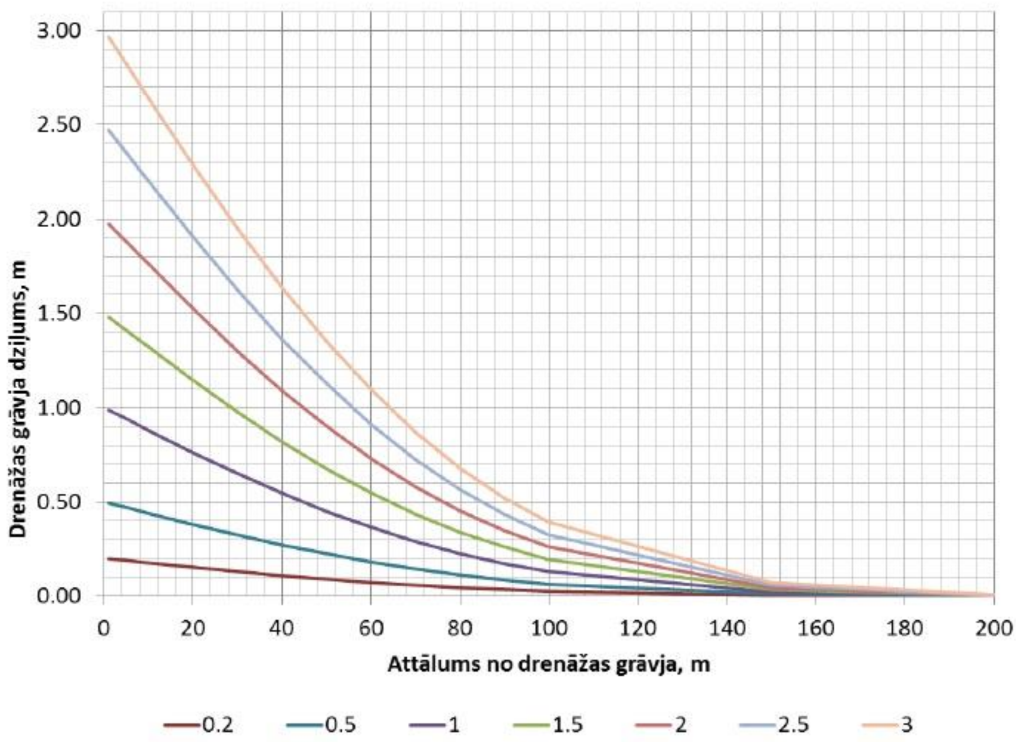


Figure 9. Decrease in water table in the peat depending on ditch depth and distance (modelled data — author: O. Aleksāns) in Northern Bogs.

3.2. Review of methods applied in groundwater research in mires

3.2.1. Monitoring programme

After on-site inspection of research area and setting the goal or evaluating what activities cause what impacts, a monitoring programme is elaborated with the planned tasks, including arrangement plans and methods for measurements, and necessary materials. Such programmes are created for all research territories. It is advisable to use all information available before launching monitoring to understand research area and specific conditions.

3.2.2. Research territory for monitoring setup

Usually, mire water table is observed in one or several representatives transects that are perpendicular to the ditch, if its impact is being assessed. If the impact of particular ditches or other disturbances have not been observed, the arrangement of monitoring sites in a single transect is not necessary. As there may be different research tasks, the transect might be arranged also in parallel to the influencing activity or object.

- In research of Melnais Lake, Rožu, Aklais, Aizkraukle, Rampa, Zaļais and other mires, a method of monitoring point transects was applied.

- Typical monitoring transects were not established in Gulbjusala Mire, W edge forests of Ķemeri Moorland. Here, the arrangement of monitoring points was based on circumstances of particular place and assessment of situation before the activities.

Transect layout in mire is chosen based on several considerations:

(1) Ditch or disturbance to be assessed is situated in place characteristic for the particular mire in order to select the best transect arrangement scheme;

(2) At what places and if any the construction of ditch dams is planned (depends on a particular site or research aim);

(3) Sometimes also the availability of monitoring wells in the research territory can be taken into account (respectively, are there ditches hard to/impossible to cross, private lands etc.);

(4) Orientation of the transect towards bog dome must be taken into account, thus evaluating impact of dominant water flow on bog water (groundwater) table in the researched area;

(5) In fen, the direction of dominant water flow must be taken into account which may differ from typical raised bog with a dome. Fen is a mire type with water inflow from groundwater, and the impact of precipitation is not excluded. Water flows can be influenced also by geographical and geological diversity of the site.

(6) Depending on the situation, there may be cases when monitoring wells must be located more deeply in water horizons.

(7) In direct relation to monitoring goal and tasks, one needs to evaluate, if hydrochemical data are necessary.

(8) analyses of available information about the research/observation territory.

In majority of cases, wells in each transect are arranged closer to each other in the vicinity of ditch, and the distance between them is greater as the distance from ditch increases (Figure 10). Transect length is usually approximately 500m, except for one of the most often used types of transects that is 250m long. The last well in the profile is located in larger distance from the source of impact (ditch) to characterise the hydrological regime in undisturbed or relatively slightly affected circumstances.

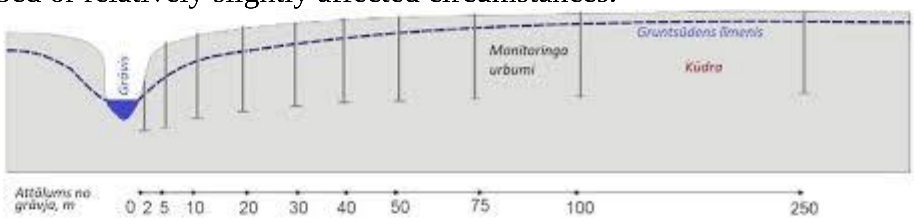


Figure 10. Schematic arrangement of monitoring wells in transect.

Transects can be created in a way that distances between the wells increase (Figure 10), or the distance between the wells can remain constant, depending on the particular situation:

- In Melnā ezera, Rožu, Akais, Bažu, Aizkraukles, Zaļais and other mires, monitoring wells are established with an increasing distance between the points.
- In Rampa, Cena and in separate places in Zaļais and Sudas-Zviedru Mires, there is a constant distance between the monitoring wells in a transect.

Advantages of transects with increasing distance between the wells

- Transect with the increasing distances between the wells enables an objective evaluation of influence of particular site or ditch on the adjacent mire, also having regard that a drawdown curve of groundwater table can develop.

Disadvantages of transects with increasing distance between the wells

- In case of transect with a constant distance between the wells, a drawdown curve will be seen less completely than in case of growing distances between the wells. Other aims can be achieved similarly with both types of transects.

- For transect rows, including individual points, one must consider also the height of the well above the sea level, thus understanding their relative layout in the research territory and assessing groundwater regime and potential flows as much as possible;

- If only one transect is created, there is a possibility that research goals will not be achieved if the territory is very specific, with high variety of conditions or if simply the area is very large;

- When creating a transect of monitoring points, their arrangement can be similar or equal to vegetation monitoring sample plots arranged in the same territory, but they may not overlap to avoid regular trampling of vegetation. Depending on situation in certain place, it would be optimal to arrange both types of monitoring not closer than 10m.

- Territory is very specific with very varying conditions, or it simply has very large area which can't be covered by one transect.

3.2.3. Possible equipment of monitoring wells

Depth, diameter and chosen materials of the monitoring wells can vary greatly, depending on goals and specifics of necessary data.

When planning the depth of borehole, one must take into account the current equipment, peat layer thickness and possible water table fluctuations in research territory, therefore these boreholes usually are 2-3m deep. Location of mire, distance from the roads and peat layer structure determine the recommended type of drill (sediments, peat, geological or ground drills), the depth and diameter of borehole suitable for the pipe intended for monitoring. In fen, the peat may be denser, therefore the use of drill which is suitable for more dense substrates may be necessary (for example, soil or geological drill).

There are more options for choosing of borehole equipment. Well constructions must ensure mutual isolation of water horizons. Depth of wells and interval of filter elements depend on mire water table and peat thickness. Well depth may not exceed the thickness of peat layer. It is advisable to set the upper border of the filter not lower than 0.3-0.5m below the mire surface; and use of 0.5m long pipe with a protective layer in the lower part of borehole (so-called sediment sluicer). Wells of groundwater monitoring must be constructed in a way that the filter is submerged in water during any seasonal fluctuations of water table. It is also recommended to expose soil layer and create bentonite seal in 30-50cm depth and up to 1m in diameter around the borehole, thus preventing surface water and atmospheric precipitations flowing into the borehole along the protective walls of pipe.

Actual application procedure of this method sets that optimum depth of boreholes (depending on situation) does not exceed 3m, with filter interval 1m in the lower part of the well, ensuring water supply in the well. 0.5m long pipe section should remain above the ground (there can be exceptions). PE or PVC material pipes (25-50mm in diameter (can be larger if necessary)) with both ends closed are used for wells. Number of transect and borehole must be written on the wells, and it is also recommended to mark their location in a territory as it helps to find the wells easier. Sometimes a support rod is put in the borehole that is fixed in the mineral ground and the monitoring pipe is attached to it (Figure 11). It prevents the movements of the pipe. Without a proper fixation, the annual remeasurement of absolute height of drill caps is necessary. Coordinates of wells must be recorded in a fixed point in LKS-92 coordinate system, and their altitude in the Baltic height system. The recommended frequency of taking measurements is around two-four times per month on average (1-2 times per month in winter when mire upper layer is frozen), and measurement data are registered in the log.

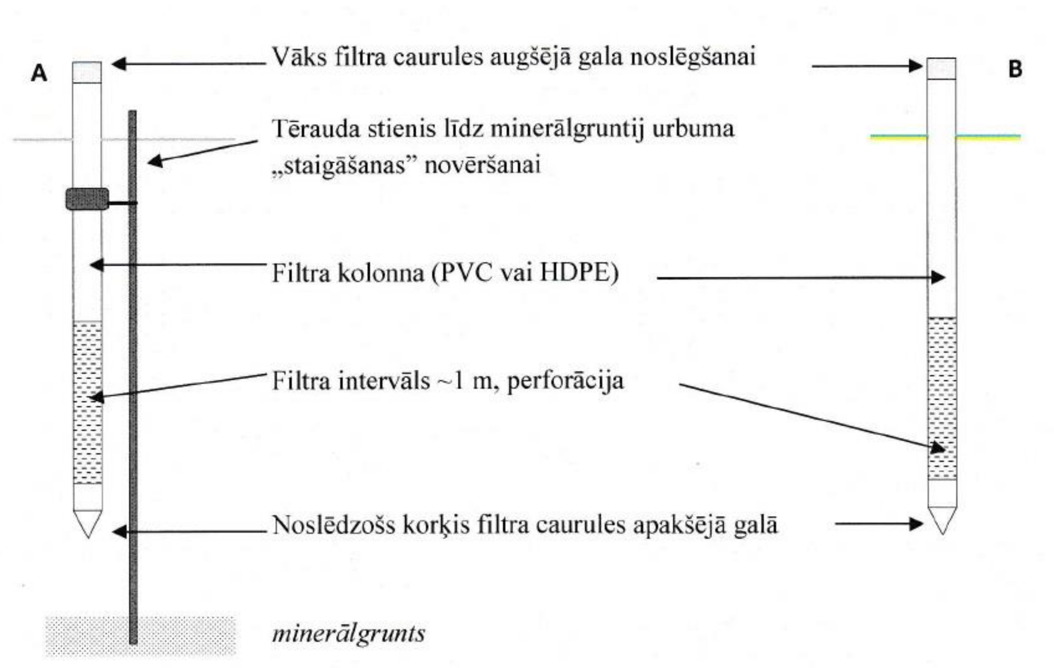


Figure 11. Construction of monitoring wells. A – well with a fixing support rod, B – well without a fixing rod; in this case, annual remeasurement of height mark are necessary.

Currently used application of well construction:

- No support rod was used in Melnā ezera, Rožu, Aklā, Bažu purvā, Cenas Mires.
- Support rod fixed in the mineral ground was used in Zaļais, Gulbjusalas, Nidas Mires.

Well openings with bentonite seal:

- Are applied in territories that are not mires, for example, in Skudrupīte and Slampe floodplains;
- From territories discussed, bentonite seal is not applied in mires.

In groundwater monitoring literature, double coating pipes, pipes with coatings, and various filter elements are often mentioned. Certified pipes with differing diameters and specific filter intervals are used. One of types of such monitoring wells is shown in Figure 12. This type of well design is necessary if not only water table measurements, but also chemical analysis of its composition are carried out, or the water is pumped off with certain regularity. It is necessary also in locations with groundwater of different tables and composition. Also surface preparation by covering and sealing the well opening is required to prevent the inflow of surface water (precipitations), as well as to prevent unauthorised persons from accessing the well opening (must be lockable).

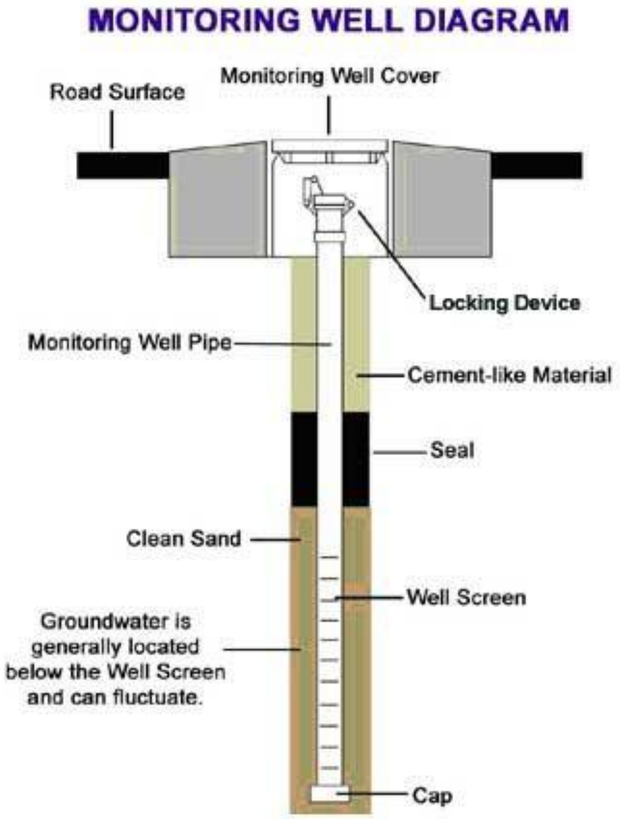


Figure 12. Schematic illustration of monitoring well.

Advantages of monitoring well with bentonite seal:

- With bentonite seal with a lockable box it is ensured that surface water does not enter the monitoring well, and also the pipe can be accessed;
- With pipes of certified material, zero impact on water composition in the monitoring well is ensured;
- Protective cover of pipe ensures that well can be used for a longer period of time or it does not become clogged by the material carried with groundwater;
- More specialised monitoring points enable more specific measurements;
- Openings above the ground are easier/easy to find in the site;
- Regular examination of height marks (both absolute height and height of well opening above the ground) help to ensure that pipe does not move in the well (that can provide inaccurate measurement data).

Disadvantages of monitoring well with bentonite seal

- Construction of a well with bentonite seal and/or lockable box is considerably more expensive. Besides, it is difficult to implement this in mires. Both the construction is difficult and also there is much higher risk that the pipe is moved with entire bentonite seal during the freezing period. At the same time, the water circulation in mires is slightly different from other types of sediments (for example, sandy soils), therefore use of bentonite seals is not crucial in mires.
- Use of certified material pipe or protective covers causes additional costs in cases if only the observation of mire water (groundwater) table is necessary and the analysis of water chemical composition is not needed. In the fens or in sediments with high inflow of clay particles, material can accumulate faster in the well pipe. For example, pipes with 1mm perforation in the raised bog practically does not clog even without filtrating cover, but in a

clayey soil, annual clogging of approximately 5cm can be observed with perforation of this size (depends on certain circumstances, as the level of clogging can be higher and lower). When elaborating a monitoring plan, approximate timespan of monitoring activity is planned, and the preferred method is selected accordingly.

- The functionality of the well can be considerably encumbered without if there is no capping in the lower end and upper part of the pipe. Ground material can enter the pipe during its insertion. Uncovered pipes can be foiled, precipitation can enter in, and increased evaporation is also possible.

- The location of well openings above the ground ensures their easy finding, construction and maintenance. However, such wells are also readily available for persons with conflicting intentions. Lids were regularly removed from well openings in Cena Mire. In some cases, wild animals have broken the pipe (even with bentonite seal). In vicinity of Ķemeri there have been several cases when pipes have been pulled out from the well and taken away. Data loggers have been stolen from wells in Zaļais Mire. If well openings are located at the ground level, there is a slight risk of surface water entering (for example from precipitations or thawing snow), as well as risk that the person performing may have difficulty locating this borehole.

- If the well lacks a fixing rod, it cannot be ensured that the pipe won't move. Even if heights of well openings are annually measured, some part of data could show certain deviations/inaccuracies, from the moment the tube starts to move in the borehole. “Anchoring” of the pipe is the best solution in terms of stability; however, it is more complicated and expensive. Besides one must take into account also the thickness of peat, as the base of support rod must be driven in the mineral ground. Also, the environmental impact on the material corrosion must be considered when choosing the equipment.

- If industrially manufactured (and/or certified) pipes are not used, the size and location of filtering element in the pipe must be inspected carefully. Filter interval is shown in Figure 12. If pipe is perforated up to the ground surface or even above the ground surface, the pipe can be entered by surface water or precipitation water, increased evaporation can take place, causing inaccuracies in measurement data. The level of imprecisions depends both on the pipe and its location, seasonal fluctuations of groundwater, and specific conditions.

3.2.4. Differences in measurement methods

In the constructed monitoring wells, depth of water saturation area (groundwater) must be determined from the well head, as well as the height of well head. Several methods can be applied for the measurements:

(1) Mechanical (acoustic) or electric gauges that are specifically produced for measuring the water table.

(2) Data “loggers” in wells together with barometric gauges.

(3) Mechanical measurement with so-called wet-tape method, which means that there is a marking on a rod or a gauge making visual differences when coming in contact with water. A simple analogy would be dry wood rod, showing the level of water saturation area. Also, a paper ribbon can be used that is placed in the well, but the changing the water level in a pipe of relatively small diameter must be avoided.

The interval of measurements varies around two times per month on average (1-2 times per month in winter when mire upper layer is frozen (in these conditions groundwater table can be relatively stable)) and measurement data are registered in the log (Table 2, Annex 4). Arrangement of the information in log or data base may differ, but there are also identical type of data when recording measurements in nature and afterwards storing data (Table 1.2). Tables can be supplemented with additional data such as: description of well, measurements of hydrochemical parameters (pH value, conductivity, calcium and iron content, etc.). For data analysis and interpretation, it is necessary to use also the information on precipitation dynamics. Therefore, when analysing data, it is advisable to use all available information that has been obtained about the research territory. For example, data on groundwater table regime obtained in subsurface monitoring in study area or its vicinity may enable the in-depth analysis of causes of water table changes.

Table 1

Example of a log when making on-site measurements.

Date	Well No.	Mire water (groundwater) table, m from the well opening	Height of the well head, m	Notes

Advantages of regular field data collection: can be performed by a trained staff; measurement procedure is not complicated.

Disadvantages of using data loggers:

- Use of data loggers alone ensure that there is no need for a large amount of time for data collection. Other methods include direct measurements with chosen regularity that requires both work and travel costs. The shortage is the high price of data loggers, as well as the possibility that they are lost or do not work, and it only becomes clear in the next measurement-data reading time on-site, when data stored by data loggers are read.

Considerations in data collection, storage and analysis:

- Simple data storage and publishing can lead to misinformation of persons not related to monitoring if there are no aims and tasks of monitoring programme;
- Data with too long measurement interval can give a general view of the territory, but some particularities can go unnoticed, such as response of territory to sudden and large amount of precipitation, intense thawing of snow, or spring flood in a specific territory;
- Water level measurements alone, without a link to volume of precipitation+, can give an incomplete understanding when interpreting data;
- Water level measurements alone, without water chemical composition analyses may provide a fragmented picture of what happens in the territory. There can be situations when the necessity for chemical occur unexpectedly, but in most cases, it is planned already in monitoring plan (monitoring programme). In situations when necessity for chemical analysis appear later, it is still possible to use portable equipment on field, or pump the water in plastic bottle for analysis in laboratory.

3.2.5. Description of hydrological monitoring method

Hydrological monitoring (monitoring of mire water table and water quality) is performed by using shallow boreholes in monitoring stations constructed in mires and surface waters (lakes, rivers, springs) in mire adjacent areas. In order to establish optimum and territory-specific mire hydrological monitoring system, summarise, analyse and interpret data in a context of general environmental monitoring, basic knowledge of mire types (raised bog, fen, transitional mire), geological hydrogeological structure and characteristics of the territory are required, and appropriate data of hydrometeorological observations must be available. Sometimes hydrogeological observations are necessary besides the hydrological monitoring, providing information about deeper aquifer, dominant processes and potential interaction with groundwater situated above.

When selecting mires where hydrological monitoring system should be established, mire area, its contribution to a hydrological regime in a particular territory, possible anthropogenic impact on mire ecosystem, biological diversity in mire and its observations must be taken into account. Carefully analysing all factors, a necessity to establish mire hydrological monitoring system must be assessed, the aim of such system must be specified, and monitoring tasks concerning mire ecosystem and subsurface water monitoring must be defined.

Depending on the established aims and tasks, the project of the monitoring system must be developed, and types and frequency of monitoring observations must be defined. Individual monitoring system must be elaborated for a particular mire. When choosing station location, it is important to collect and analyse all available information; that must be performed by a highly qualified specialist or a group of specialists with basic knowledge in geology, hydrogeology and hydrology.

In order to elaborate optimum bog water monitoring system and choose certain locations of stations, the following must be specified by using all available materials of geological, hydrogeological and hydrological research:

- Bog water replenishment sources (mire type);
- Mire interaction with surface and subsurface waters;
- Thickness of peat layer in mire;
- Type and relief of bottom sediments.
- Terrain characteristics and their relation to mire as well as in regard of interaction with surface and subsurface water, including infiltration and run-off.

3.2.6. Principles of choosing and setting up the monitoring stations

A row of shallow boreholes, which arrangement largely depends on mire type, must be created for the purpose of mire hydrological monitoring. Number of wells and distance between them depend on mire size and monitoring aims and tasks.

Transect of boreholes in an undisturbed raised bog can be created for the achievement of specific tasks. However, there might be situations where this transect must start with boreholes on either sides of mire border, and hydrological monitoring can also be planned, and in such case boreholes are no longer referred to as shallow and the same monitoring cannot be implemented in the mire itself. Row of wells boreholes must be arranged perpendicular to the mire edge towards the centre (in raised bog — towards the dome), including vegetation monitoring plots to an extent possible, but making sure they do not overlap (preferably no closer than 10m) to avoid trampling in vegetation plots. Similar configuration should be created in large mires where the peripheral zone might have fens, then the transitional mire, and raised bog in the centre. The same principle can be applied to assess the impact of drainage ditch. There can be exceptions, depending on the specific characteristic of the site and aim to be achieved.

In fens partly or directly fed by the surface water (river or lake) and which are situated in river valleys or terrain depressions of lake, the starting point of the row of monitoring boreholes is the water replenishment source (monitoring station for the observation of river or lake water level). For this purpose, borehole can be used, but also a fixed measuring rod can be installed in a watercourse and water bodies (lakes, bog pools etc.) from which the water level and its fluctuations can be recorded.

Number of observation stations (boreholes) in the row depends on mire area, monitoring tasks and the level of detail required. In a small mire of simple geological structure and natural or slightly altered conditions, mire hydrological changes can be characterised by a monitoring system with 3-5 observation stations, arranged in one line (transect). In a large mire of more complex geological structure, modified surface and underground water regime and run-off, it might be required to create several rows of boreholes, and the number of wells depend on row length and defined tasks.

In order to monitor mire water, unconfined and confined groundwater, a construction of boreholes must ensure that water horizons are isolated from each other. Depth of wells and interval of insertion of filter element is selected depending on mire water table and peat layer thickness. Borehole depth may not exceed the thickness of peat, if it is intended for mire water observations; it must submerge into the water horizon which is a target of hydrological monitoring, at least for 1m. Therefore, the upper boundary of filter of mire water monitoring wells should preferably be at least 0.3-0.5 m below the mire surface. In lover part below the filter, 0.5 m long pipe with protective cover can be constructed. Borehole depth may vary depending on above mentioned factors, but its range is 2-3m. In undisturbed raised bog, even a 1.5m deep well is sufficient for the observation of hydrological regime.

Construction of groundwater monitoring wells must ensure that filter elements are submerged during any seasonal water table fluctuations. In a vicinity of well opening, slight compaction of peat is recommended, but the creation of concrete ring should be avoided, thus preventing surface waters and precipitation from entering the borehole along the pipe walls. However, it is necessary to fix the pipe to prevent its moving in the peat. The simplest solution is a rod driven up to the mineral ground (and into it, if possible), situated next to the pipe that is fixed to rod.

Apart from groundwater table measurements, water composition analyses or assessment of parameters depend both on situation and aims to be achieved. Nevertheless, typical bog water is characterised by relatively low pH value and conductivity.

Installation of monitoring stations

Monitoring wells can be constructed only by specially trained personnel with a proper technical support. For the establishment of monitoring system (boreholes), a licence must be received from the Licensing Department of the State Environmental Service; however, some monitoring stations have been installed also without a licence. All requirements listed in the licence must be met; relevant description of activities taken and sediment profile in coring must be provided, depth at which water saturation zone appears must be recorded. For each borehole, location must be recorded (coordinates), as well as absolute height marking according to the Baltic height system. During the construction of the wells, it is possible to perform analyses of water hydrochemical parameters or take samples for analyses in a laboratory even if such measurements will not be continued during the monitoring. Parameters to be measured can include pH value, conductivity, temperature, iron, calcium content, etc.

Monitoring can be carried out by above described methods, it can also include regular on-site measurements, and the boreholes can also be equipped with automatic data reading devices. They have similar operating principles, but may differ significantly in the options and thus in the final price. Price of the simplest models is approximately 400 EUR (https://www.fondriest.com/solinst-levelogger-junior-edge-water-level-logger.htm), while more regular variants cost approximately 600 EUR. Differences may be in a number of parameters that such a logger reads and stores. There are also expensive solutions available that send obtained data and thus enable the instant follow-up of water fluctuations. The simplest solutions include automated data storage at the set interval. However, annual or more frequent on-site data readings at boreholes by using a laptop and specialized software is necessary that can also increase costs. Besides, atmospheric pressure measurements are necessary for using data obtained by the loggers. Such data can be read by barometric loggers (at about the same price range as those intended for water). It is possible to install several barometric loggers in very complicated and large research territories, but in simpler cases one device is sufficient to obtain atmospheric pressure measurements to compensate for the water column pressure (in a borehole tube). Such logger must be installed in a typical location of the territory, at the level of ground surface.

4. METHODICAL GUIDANCE FOR USING REMOTE SENSING DATA FOR MONITORING OF HABITATS OF THE EUROPEAN UNION IMPORTANCE

Methods of remote sensing are used for a long period of time in researching of mire vegetation and dynamics. Researchers from the Institute for Environmental Solutions, who use Airborne Surveillance and Environmental Monitoring System ARSENAL, have experience in analysing remote sensing data.

As current remote sensing system was established, initially only in aerial photography stage, it was noted that aerial photography can be successfully used in mire mapping (both topographic and topical) and observation.

As Earth Observation System was integrated into remote sensing, it brought another scale to territory observation and possibilities to record a course of natural phenomena, processes and changes with varying spatial and spectral resolution. Spatial resolution (in digital environment it is the length of edge of image element (a cell or a pixel) in nature) still remains one of the key parameters.

In current state of development of remote sensing there are great opportunities to use current technologies as well as the cutting-edge technological solutions, firstly, unmanned aircraft (drones etc.), digital cameras, thermal cameras, laser scanning technologies (LiDAR) and software solutions.

If significant impact is expected in any of territories (or it has already taken place), it is important to assess characteristics of potential impact and influence it has on territory's objects (at first, geological and hydrological environment, flora and fauna...), then record their condition and monitor, record and analyse changes by estimating if the predicted impact (if such assessment is made) manifests and if there is a need to adjust projects or certain activities.

For already 30 years, professionals and interested persons in Latvia can observe changes in nature by using regularly obtained orthophoto maps, available firstly in the Map browser of Latvian Geospatial Information Agency (LGIA) and other browsers. Good quality spatial material excellently shows the state of the geographical environment at a certain moment, while a series of such records enable seeing the changes in dynamics. Starting this year, LGIA ensures downloading the most recent orthophoto maps and LiDAR data providing independent data visualisation and analysis possibilities.

Spatial resolution (Fig. 3) increases with each new orthophoto map cycle, whereas the frequency of capturing orthophoto maps decreases.

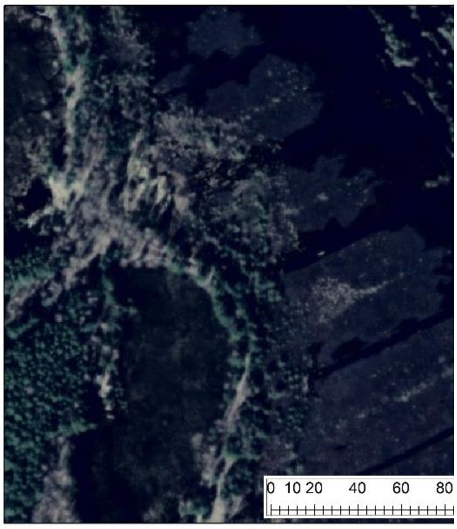
However, the intended interval of 3 years can be too long, because in the meantime the peat extraction might be launched in mire and then it would not be possible to get an information on a state of certain location (territory) at a certain time. In such case, unmanned aircraft are very helpful, as they capture high spatial resolution images and, when installing and surveying on-site aerial photo markers, it is possible to obtain high precision and resolution orthophoto maps and also territory terrain and 3D models of vegetation. It must be added that it might be complicated to get an accurate spatial model of land surface in an aerial photo due to vegetation, especially in dense stands. But in many places it is possible to notice changes in ground surface or in level of water bodies and to take necessary measurements.

Not only vertical, but also inclined and perspective views can be captured. By using thermal cameras on drones, it is possible to survey and analyse thermal changes in the environment.

However, for a more detailed and accurate information in this regard, it is advisable to use laser scanning data (LiDAR).

Since there is no information yet about the incoming laser beam cycle , in other cases in Latvia one can use also laser scanners, intended for drones or other unmanned aircraft.

Year 2007



Year 2010

Yea 2013

Year 2016

Figure 1. Renaturalisation of post-harvested peatland in eastern part of Ķemeri Mire from 2007 to 2016 (fragments of orthophoto map created by SLS and LGIA).

How often would supervision and impact assessment should be made? Most probably these issues should be decided in expert discussions, because so far, such method has not been elaborated. When improving the method, the minimum period and minimum requirements must be set forth.

Within the framework of Biodiversity Monitoring Programme (BDMP), which follows from the European Habitats Directive, examination of changes of habitat area and data updates were required once per reporting period, i.e. every six years (Auninš, Lārmanis 2013).

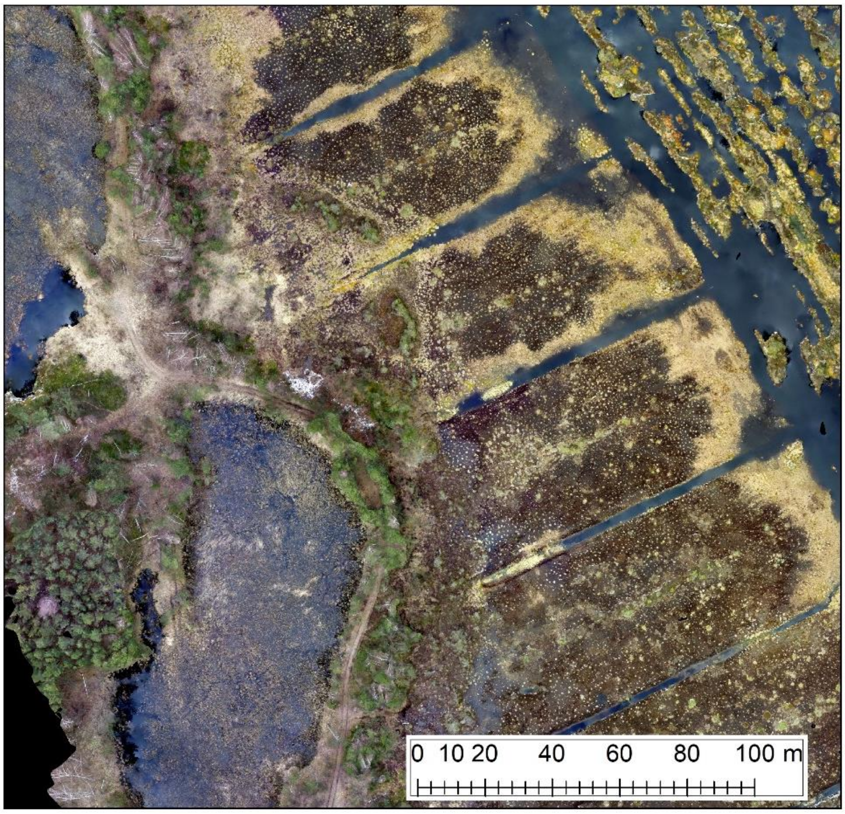


Figure 2. Fragment of orthophoto map captured by a drone, in post-harvested peatland in the eastern part of Ķemeri Mire (year of 2016).

In many cases, if a territory to be monitored is either large or the company has many properties to monitor, satellite data, especially Sentinel, make a successful solution: both optical and radar recordings are with a lower resolution if compared to aerial photos, but their advantage is found in high repeatability that is, nevertheless, restricted by frequent cloud cover in skies over Latvia.

Satellite data can be used as operative, topical and independent information that one can get in the comfort of their office, and it ensures high periodicity (images are taken every 5 days), and each photo has metadata (date and time of capture, satellite etc.).

By using the data obtained, they must eventually, but better from the beginning of the project, be integrated in any Geographic Information System (GIS) environment, allowing to maintain, correctly analyse and visualise spatially connected data.

Orthophoto map and satellite images can be compared visually in GIS and using image processing software or relevant tools would give more qualitative results.

It must be taken into account that images captured in various vegetation seasons and from various remote sensing platforms may differ in quality and spatial resolution, therefore changes must be judged carefully.

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Annex 1 General information about selected vegetation monitoring systems

Site, habitat code	Reason of monitoring	Started/repeated	Number/length of transects	number of sample plots		Distance between sample plots or their centres, m	Shape/diameter of sample plot, m	Notes
				total	in transect or group			
Teiču purvs 7110*, 7120	LVMI “Silava” scientific research	1990/ 1995	7 / 100	120	20	5	1 m²	Moisture and acidity values assessed additionally, according to ecological scales
Teiču purva masīvs	Administration of Teiči Nature Reserve	2004	1 / 2300	73			1 m²	Blocking of ditch
Ķemeru tīreļa R mala (ĶNP) / 7110*	LIFE10 NAT/LV/000160	2014/2015, 2019	4/50	20	5	10	round/4m	
Zaļais purvs (ĶNP)/ 7120	LIFE10 NAT/LV/000160	2014/2015, 2019	5/50	25	5	10	round/4m	
Rožu purvs, 7110*, 7120	LIFE08 NAT/LV/000449	2010/2012,2013	5/50	26	6	6	round, 4 m	
Aklais purvs, 7110*, 7120	LIFE08 NAT/LV/000449	2010/2011,2012,2013	6/50	30	6			
Aizkraukles purvs, 7110*, 7120	LIFE08 NAT/LV/000449	2010/2011,2012,2014	6/50	25	6			
Melnā ezera purvs, 7120, bijusī kūdras ieguves vieta	LIFE08 NAT/LV/000449	2010/2011,2012,2013	6 2	32 14	6 7			
Rampas purvs AAA “Adaži”	LIFE06/ NAT/LV/000110						100 m²	Sites of “activity” and “background” are separated
Cenas tīrelis 7110*/7120	LIFE13 NAT/LV/000578	2005-2008		25			10 x 10 m (includes 3 1x1 m)	Influence of rewetting is evaluated also in Vasenieku and Klāņu Mires

Ķemeru tīrelis (ĶNP) bijusī kūdras ieguves vieta (frēzlauki 7120	LIFE02 NAT/LV/008496	2007; annually repeated except 2017 and 2018		28			around, diameter 4 m	
Raganu purvs pie Sēravotiem 7230	LIFE11 NAT/LV/000371	2013	random arrange ment	6			5 x 5 m	Removal of shrubs, experimental mowing
Šlīteres purviņi pie Bākas 7230	LIFE11 NAT/LV/000371	2013/2014,2 015,2016	random arrange ment	8			5 x 5 m	Removal of shrubs, experimental mowing
mikroliegums “Dubļukrogs”	Personal interest of expert	2013/2014,2 015,2016	random arrange ment	6			5 x 5 m	Management by LVM: removal of shrubs, experimental mowing in a couple of sites
Engure pie Orhideju takas un Lepstes lāmas	LIFE project	2017		33			30 1 x 1 m three 10 x10 m (nine 1 x 1 in each)	
Ķemeru purvā 7110*, 7120	LIFE14 CCM/LV/001103	2017		13	23		1 x1 m	
Laugas purvā 7110*, 7120				20	10		1 x1 m	Sites of action and reference area
Aizkraukles purvs, DL “Aizkraukles purvs” 7110*/ 7120	Peat extraction license requirement of State Environmental Service (including groundwater table monitoring)	2014/ 2019		30			round, diameter 4 m	
Sloku purvs, 7110*, 7120	Dolomite extraction licence requirement of State Environmental Service (including groundwater table monitoring)	2016/2019	3/100	20				
Melnsalas purvs 7110*, 7120	Dolomite extraction licence requirement of State Environmental Service (including groundwater table monitoring)	2016/2019	1/1000	10				

Dzelves-Kroņa purva Z daļā, DL "Dzelves-Kroņa purvs"/ 7110*, 7120	Peat extraction license requirement of State Environmental Service (including groundwater table monitoring)	2018.	3/ 200	27	9, 3 groups by 3	3	round/4m	Peat extraction and influence of respective ditches
Dižās aslapes *Cladium mariscus* monitorings pie Kaņiera un Labajā purvā Engurē, 7210*	Personal interest of expert	2013/2014-2019 except 2017 and 2018; in Engure since 2018	random arrange ment				2 x 2	Different management (shores of Kaņieris Lake, Labais Mire, Engure) – experimental mowing (hay collection or leaving on site), or unmanagement (control)
Kaņieris 7230	National Monitoring Programme	2003 to 2016	random arrange ment	3			10 x 10 m	Expert comment: sample plots are established in forest/mire transitional zone therefore it is hard to continue monitoring (sample plots must be established in homogeneous areas)
Kaņieris 7230	Initiative of Ķemeri National Park	2008 to 2019	random arrange ment	6			2 x 2 m	
Rāķa purvs, Ozolmuižas purvs Lielais purvs,	Initiative of SIA Klasmann-Deilmann Latvia	2017/2018 – every 5 years			group of 4 2 m² sample plots		8 x 8 m	Supplemented by hydrological monitoring

Annex 2 Natura 2000 monitoring field data form

(Excel file attached)

Annex 3 Vegetation monitoring field data form

(*number of rows according to the technical layout*)

Vegetation monitoring field data form

Expert	
Date	
Mire name	
Plot No.	
Coordinates	
Photo	
Total number of species	
E3 Overstory layer	
E2 Shrub layer	
Ezk Dwarf shrub	
E1 Herbaceous layer	
E0 Moss layer	
Cover, %	
Total cover of E3 canopy layer	
Total cover of E2 shrub layer	
Total cover of Ezk dwarf shrub	
Total cover of E1 herbaceous layer	
Total cover of E0 moss layer	
Cover	
E3 Overstory layer	

Weather:	
Structures	
Tall hummocks	
Low hummocks	
Hollows	
Area without vegetation	
Open water	
Litter	
Other	
Shoots	
Pinus syl	
Betula pub	
Betula pen	
Cover	
E1 Herbaceous layer	

E2 Shrub layer			
Dwarf shrub layer (Ezk)			
Betula humilis			
Betula nana			
Myrica gale			
Salix rosmarinifolia			
E0 moss and lichen layer			

Notes:

Annex 4 Hydrological monitoring field data form

Well No.	Coordinates	Absolute height of opening, m	Well depth, m	Date	Opening's height above ground, m	Water table, m from the well opening	Water table (from ground surface), m	Notes

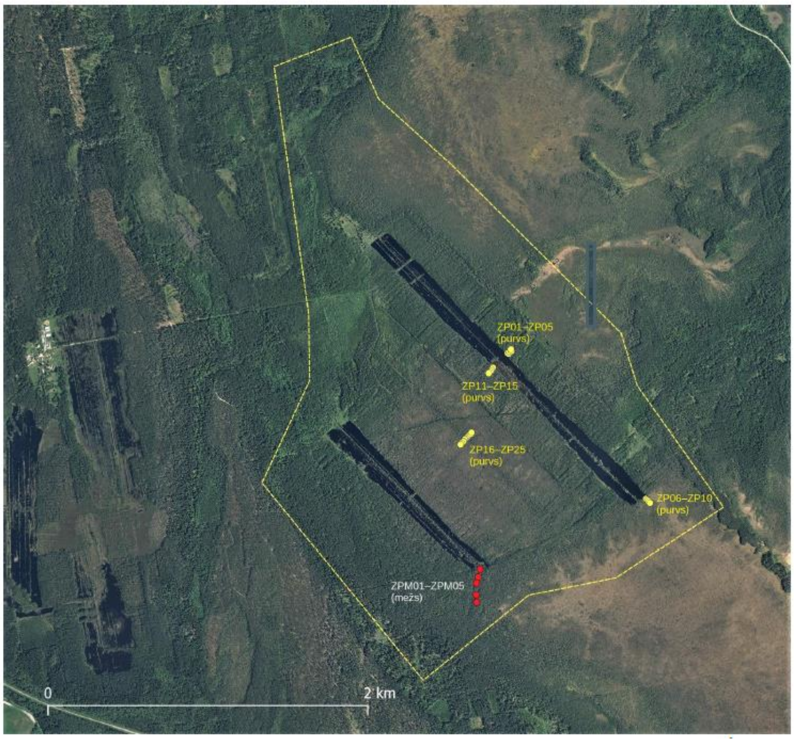
Annex 5 Description of vegetation plots in Pelēču ezera purvs Nature Reserve.

2019. gada 17. augusts											Pe									
dabas liegums "Pelēču ezera purvs"																				
Parauglaukuma Nr.	Pe1	Pe2	Pe3	Pe4	Pe5	Pe6	Pe7	Pe8	Pe9	Pe10	Pe11	Pe13	Pe15	Pe1717	Pe19	Pe21	Pe23	Pe25	Pe27	Pe29
		foto DZ						foto												
Ph			5,9		6,11			6,05		6,12				6,45				6,57		
ūdens t			18		18,8			21,9		19,3				19				20,2		
gaisa t			17,7					21,1		19				18,9				22,2		
izteiktas struktūras												augsti								
Kopējais sugu skaits																				
E3 Koku stāva kopējais segums, %	0	0	25	0	20	0	0	0	0	13	20	35	0	0	0	0	0	0	0	0
E2 Krūmu stāva kopējais segums, %	46	28	38	33	42	62	6	10	34	40	50	37	27	30	16	11	7	2	19	20
E1 Lakstaugu sstāva kopējais segums, %	67	64	19	92	42	77	44	49	37	48	57	58	86	51	22	51	65	58	47	31
E0 Sūnu tāva kopējais segums, %	90	98	75	53	100	87	70	50	80	75	100	111	65	53	55	85	45	21	69	68
Projektīvais segums																				
E3 koku stāvs					20					13	20	45								
Pinus sylvestris					20					3		25								
Betula pubescens										10	20	20								
Salix sp.																				
E2 krūmu stāvs	9	12																		16
Amelanchier spicata												2								
Alnus incana	3																			
Betula pub	7	5	2	7	5	22		1	20	10	7	1	10	1	5	7	3		3	6
Frangula alnus											5					1				
Picea abies				5		12					5									
Pinus syl		5	3	4	25	15	2	2		3	25	30	1	20		1			4	10
Salix cinarea								1	2		5			2						x
Salix sp.		2	2	2	2	2		x		1										
Zemo krūmu stāvs																				
Betula humilis	35	15	30	10	10	10	3	3	2	25	3	3	15	7	10	3	2	2	12	4
Salix rozmarinifolia	1	1	1	5	x	1	1	2	10	2		1	1	1	1	2	2	x	x	1
E0 sūnu un ķērpju stāvs	90	98	90	55	95	85	70	50	80	70	95	95	65	55	55	82	50	25	70	70
Anura pinguis			x	x		x	x			x				x			x			
Aulocomium palustre			5								3						2			
Brachitecium sp.																x	x			
Brium pseudostrictum	5												x		x		x		x	x
Calliergonella cuspidata	35	10	10	20	15	15	10	2	2	30	5		15			1	7			
Calliorginella gigantea	2							x					x							
Chiloscyphus pallescens	1																			
Climacium dendroides										1										
Compilium stellatum	2	5	10	10	10	15	15	15	20	30			10	35	50	70	20	1	65	50
Dicranum polysetum			1								x									
Drepanocladus revolvens	5	5	5	5	10	10	10	20	3	5	3		15	15		5	15	12		15
Fissidens adiantor															x					
Hylocomium splendens						1	x													
Lophocolea sp.																			x	
Pleurozium Shcreberi		x	1				x										x			
Pellia epiphylla						x	1	x						x		1	x	x	x	
Plagiomnium ellipticum				x																
Polytrichum juniperum		5			x															
Ricardia chamedryfolia							x	x		1	x		x	x	x		x	x	x	x
Rhizomnium pseudopunctaum	25	5	3	5	1	1	1	5		1	1		4	2	1	x	x	1	2	1
Scorpidium scorpioides				10			3	3	x	x	2			1	4	5	2	7	2	2
Sfagnum angustifolium		10			5	3		x	15		5	5								
Sfagnum contortum		20	25	2	25	15	15	5	40	7	75	80	3			2				
Sfagnum fallax		10	10	1	30	25					3	15	3							
Sfagnum magelanicum					3				x			5								
Sfagnum palustre	5	10	1			2					2									
Sfagnum rubellum		2										5	15							
Sphagnum russowii	10																			
Sfagnum squarrosum		1	4		1		15		x		1	1								
Sphagnum warnstorfii		15																		
Calliergon stramineum				x						x				x						
Projektīvais segums																				
Agrostis canina	x		1	x		x	1		x	x	x	1		x			x		x	x
Alnus glutinosa	x																			
Andromeda polifolia		2	1	2	x	5	5	2	5	15	20	25	20	20		10	1	5	7	7
Betula pub	1	1	1			3	5				x			x	x	x	1			x
Cardamine pratense																x		x		
Carex elata	1	1	x	1		x										x				
Carex lepidocarpa	2		12				x									2	1	2	x	
Carex diandra		x		x				x												
Carex dioica		x										x								
Carex lasiocarpa	10	15		10	15	15	10	10	10	7	8	5	1	10	7	1	5	7	10	15
Carex panicea	x															3				
Carex rostrata			x	x	1	x	1	2	x	3	x		1	1		4				
Carex sp.				x				1												
Comarum palustre	5	5	2	2	2		2	3	5	5	3	1	5	3		2	2	5	2	
Dactylorchiza incarnata		x		x							x									x
Drosera anglica				x			x				x		x	x	x	1	1	1	1	
Drosera rotundifolia	x	x		x	x	x				x		x		x	x		x		x	
Dryopteris sp.	x																			
Eriohorum polystachion													x				x			x
Equisetum fluviatila	1												x							
Filipendula ulmaria				x																
Frangula alnus											x									
Galium palustre	x		x																	

Annex 6 Arrangement of plots in transition mire at Pelēči Lake and coordinates

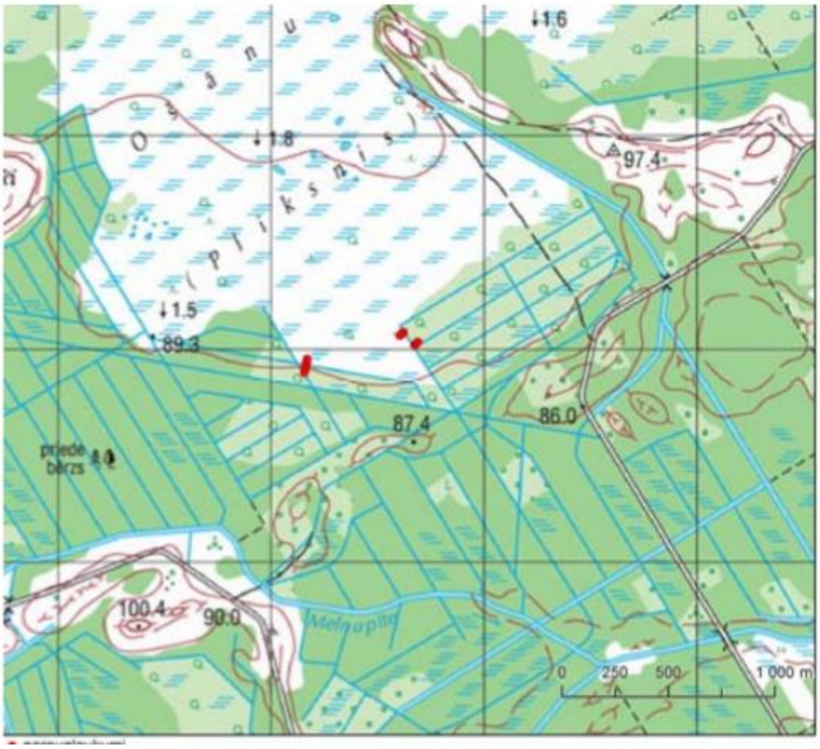
X	Y	Plot.Nr.	Photo
668777	227796	PE01-19	
668774	227810	PE02_19	
668778	227826	PE03_19	
668779	227838	PE04_19	
668780	227851	PE05_19	Photo pointing S, W, E
668781	227867	PE06_19	
668784	227882	PE07_19	
668787	227897	PE08_19	Photo pointing W and E
668788	227913	PE09_19	
668790	227927	PE10_19	
668791	227943	PE11_19	
668794	227973	PE13_19	
668797	228000	PE15_19	
668800	228029	PE17_19	
668800	228059	PE19-19	Photo pointing S, W, E
668778	228078	PE21_19	
668724	228106	PE23_19	
668752	228092	PE25_19	
668697	228120	PE27_19	Photo pointing S, W, E
668669	228134	PE29_19	

Annex 7 Examples for arrangement of transects and plots

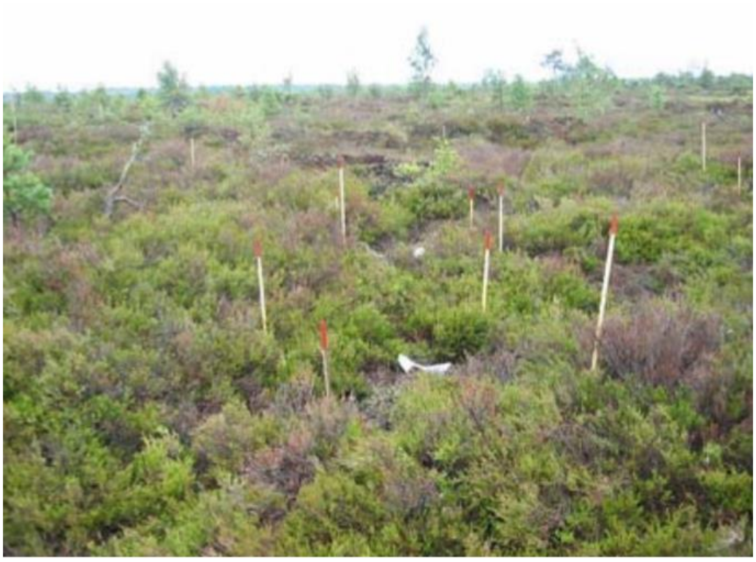


Arrangement of sample plots in Zaļais Mire. Vegetation plots are depicted with yellow points. Plot arrangement scheme is based on Orto photomap of 2017 from Latvian Geospatial Information Agency © (Priede, 2019).

Transects of plots in Kroņu-Dzelves purvs Nature Reserve for the evaluation of peat harvesting influence. Google maps were used as they allow simple storage of the location of chosen point according to coordinates (Silamiķele, 2018).



Arrangement of vegetation monitoring plots in Rožu Mire (Nature management plan for Rožu purvs Nature Reserve).



Cena Mire vegetation monitoring plot, photo M. Pakalne (Nature management plan for Cenas tīrelis Nature Reserve).

Vegetation monitoring plot
in Kroņu-Dzelves Mire, photo I.Silamiķele.