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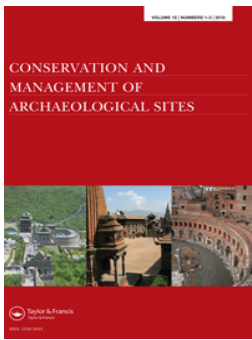
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Preserving Medieval Farm Mounds in a Large Stormwater Retention Area

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The Netherlands has denoted large areas as stormwater retention areas. These areas function as temporary storage locations for stormwater when rivers cannot cope with the amount of water. A large area, the Onlanden — 2,500 hectares — was developed as such a storage area between 2008 and 2013. This peat area contains up to 300 medieval housing areas. These ‘peatmounds’, named after the current visible small mound, were explicitly mentioned as a preservation goal in the project. The preservation of the peatmounds during and after the project has been guaranteed by a combination of protective measures, research, and monitoring actions. At first a risk evaluation was performed, followed by a monitoring project focusing on the preservation of the organic part of the mounds. This evaluation showed that the rewetting of the mounds might improve the overall preservation. A total of fifteen monitoring stations were a-selectively distributed over the total area, covering the four main types of land use. The measured parameters at these stations focus on the desiccation/rewetting effects. The second threat, as determined in the risk evaluation, is the growth of deep penetrating plants. These roots might disturb the archaeological profile. Preventive coverage with plastic and up to a metre of soil could prevent root growth into the archaeology. An experimental coverage showed the effectiveness of this technique, but also the risks. This paper focuses on the lessons that can be learned from this six-year project, the monitoring results, and clearly shows the benefits of a combined approach in large-scale projects.

KEYWORDS monitoring, water level, redox potential, mitigation measures, peatmound

Introduction

The Netherlands has seen an increase in flood risk from rivers. Due to climatic changes and upstream alterations, the amount of peak flow in rivers has increased in the past

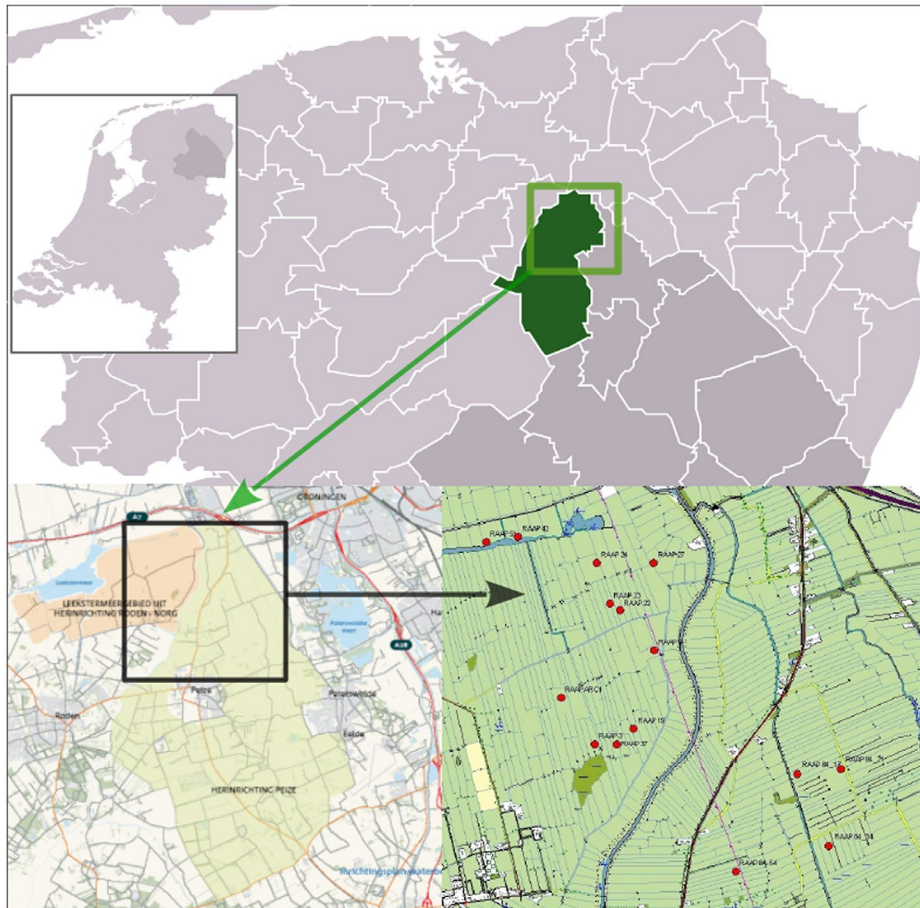


FIGURE 1 Map of location of the Onlanden in the Netherlands. Left bottom: Project area. Right bottom: monitoring locations.

decades. This increased risk, together with near floods in the 1990s, led to a policy of creating more space for natural water flow and storage. This programme was sped up by a temporary law during the years of the recent financial crisis (2008 to 2011). This law (<http://wetten.overheid.nl/BWBR0027431>) made it possible for the Dutch government to set aside long-lasting procedures for large infrastructure projects. One of these projects dealt with creating a water storage area that serves to protect the city of Groningen. The project area, the ‘Onlanden’, consists of low-lying peat areas that had been drained for decades for agricultural purposes (Figure 1). A large quantity of archaeological features can be found embedded in this area.

The area was inhabited by small family groups in the medieval period. The house types they used are extensively described in Nikolay (in prep.). The current remains are in general visible as small heights in the landscape (Figure 1), the so-called mounds. These mounds are referred to as ‘peatmounds’, as they were believed to consist of layers of peat, or because they are located in a peatland. The name does

not mean that they consist of a mound of organic rich peat, or that peat was the original building material.

The average peatmound has a height of 20–40 cm above the surrounding area, and is found in a wide boundary around the former waterway in the area. Previous research on a small number of peatmounds (Scholte Lubberink, 1994) showed a standard morphology in which layers of peat and clay altered. Many artefacts could be found therein. The development of a water storage area in the Onlanden led to a number of formal protection actions, and an *in situ* preservation project. The preservation conditions have been monitored. The decisions on what to do at what stage were made in a setting of time pressure, and some political turmoil.

This paper aims to describe the chosen risk assessment, protective measures and the method of monitoring followed, based on the general monitoring performed by other parties in the area. Some results of the monitoring are shown, but readers should refer to the technical reports for full details.

Setup of the project

Before the beginning of the project, a field inventory was conducted (Schepers, 2008), which revealed that it was rather difficult to find this layered morphology in manual corings. The lack of proof for layered structures in the corings did at that moment not call for a change in the model for the general morphology of a peatmound. The rest of the risk assessment and monitoring setup relied heavily on this model.

Dutch law states that an overall environmental risk assessment has to be produced before any development project can commence; a so-called milieu effect rapportage (MER, in English ‘environmental impact assessment’). The MER for the Onlanden project included a list of parameters/functions that had to be monitored throughout the project. One of those was ‘archaeology’. The inclusion of this line was the sole reason for the project organization to search for a partner that could make a plan for the monitoring of the archaeology.

The law on archaeology states that any project should warrant the safeguarding of archaeology. The safeguarding should include any good archaeological research. During all groundworks, an archaeologist had to be present, and if any of the peatmounds were to be damaged, a full-scale excavation was to be executed. There is however no standard method of *in situ* protection. The main guide is the Archaeological Monitoring Standard (Smit, et al., 2006). That document provides a toolbox of techniques, but does not include a decision tree (Vorenhout, 2011) or similar to choose the parameters to monitor (Janssen et al., 2013), nor what steps to take and in what order.

Risk assessment

The flooding of a large area has never been studied in relation to preservation *in situ* of archaeology. In order to come up with an assessment of potential monitoring targets, a risk assessment was set up for the peatmounds. This entailed two parts. First, the risk of flooding and land use change related to that was to be covered. A list of potential threats from flooding was created, and following discussions with archaeologists and interpretation by the author, these risks were ordered by threat level.

Table 1
 NUMBER OF MOUNDS WITH MENTIONED THREATS ENCOUNTERED. THESE THREATS WILL PERSIST WHEN NO DEVELOPMENT OF WATER STORAGE WOULD OCCUR (SCHEPERS, 2008; VORENHOUT, 2008B).

Current threat	Oxidation / humified peat	Desiccation	Trampling	Ditching	Removal	Driving	Other
number	25	27	10	14	1	5	10
Percentage of total	45.45%	49.09%	18.18%	25.45%	1.82%	9.09%	18.18%

Table 2
 FUTURE CONDITIONS AND THREATS SORTED BY THE EXPECTED WATER TABLE (VORENHOUT, 2008B). + FAVOURABLE CONDITION, - LESS PREFERRED, - UNWANTED.

	Similar water level	Fluctuating near archaeological level	Permanently wet / under water
Oxidation / humified peat	+/-	-	+
Desiccation	+/-	+	++
Inaccessibility	+/-	-	-
Deep rooting plants	0	-	-

Second, the current situation, with continuous dry conditions and use as grassland, also needed to be assessed for threats (Schepers, 2008). This would give the baseline level (Table 1).

This step is usually not included in an archaeological risk assessment, and might not be necessary for each project. However, this step helped in the discussion of the hypothesized threats and in ranking those future threats.

Then, the risks were appointed to each peatmound, creating a background database with local risks and threats. The peatmounds were ranked according to their location in the three general groundwater levels: (1) high water/wet conditions, (2) alternating near archaeological level, and (3) less dry/similar level (Table 2). The third criterion was the archaeological information value, as often used in Dutch archaeological valuations by archaeologists (Table 3). As an extra step, a test monitoring setup was installed in peatmound 5, which was excavated in September 2009 (Figure 2).

Design of the monitoring and selection where to measure

The monitoring plan covered most, if not all, aspects of the identified risks as described in Table 2.

In general, three groups of threats, and thus monitoring parameters, were made: (1) vegetation development, (2) oxidation/desiccation and rewetting, and (3) physical damage and inaccessibility. Future physical damage (3) was not included in the monitoring as that was part of the watch and brief actions on site. The matter of inaccessibility could also not lead to monitoring but was taken as a fact. The inaccessibility of the site for near future research raised the awareness and attention of the archaeologists involved. This fact was a strong driver for political pressure, but it cannot be seen as an actual threat to the physical archaeology.

TABLE 3
THE THREE CATEGORIES OF QUALITY AND TYPE OF LOCATION OF 4 (STRATA) × 3 RANDOMLY SELECTED PEATMOUNDS. THE FOURTH IN EACH GROUP SERVED AS A RESERVE, WHICH COULD ONLY BE USED WHEN ANOTHER PEATMOUND WAS REALLY UNSUITABLE FOR MONITORING. BOLD ID: ACTUALLY SELECTED IN FIELD FOR INSTALLATION. THREE ADDITIONAL PEATMOUNDS WERE SELECTED FROM THE NATIONAL MONUMENT (17, 21 AND 34) TO INCREASE SPATIAL COVERAGE.

PeatmoundID	Archeo group	Physical quality	Future water level category	Stratum (combined grouping)	Meteo station / remarks
24	1	1-	2	1	Covered spring 2012
ARC1	1	1-		1	
3	2	1-	2	1	
38	1	1-	2	1	reserve
19	1	2+	2	2	Meteo + Covered spring 2012
27	3	1-	2	2	
9	3	1-	2	2	Ended 24-03-2011
33	2	1+	2	2	reserve
84-54	4	1-		3	Meteo
22	3	1+	1	3	Meteo / Ended 15-04-2011
51	1	2-	2	3	
44	2	1-	2	3	reserve
49	5	2-	3	4	Unselected
37	4	2-	2	4	
42	4	2-	3	4	Meteo
23	4	2+	2	4	



FIGURE 2 Excavation of mound 5 (left) and the monitoring equipped used (right).

Vegetation

The Onlanden area, as part of the nature infrastructure in the Netherlands and European Union, was monitored for vegetation change in time following a standard for coverage of vegetation types. However, these maps are based on the polder level, much larger units than the scale of a peatmound. The vegetation descriptions usually do not include the different vegetation on the peatmound, and regard the peatmounds as anomalies, rather than the focus point. Therefore, the vegetation type and cover on the peatmound was included as an annual parameter. From these vegetation descriptions, the cover of deep rooting species was estimated.

Oxidation/desiccation and rewetting: soil chemistry

The soil moisture levels were expected to increase, as the water table would rise after letting in the water. This should in general lead to more reduced soil conditions (Unger, et al., 2008; Vorenhout, 2015), good for the preservation of organic remains and soil layers (Huisman, et al., 2009). This change was monitored by measuring soil moisture, redox potentials, and temperatures — all at multiple depths. Soil moisture gives an estimate of changes in water filled pore space. The redox potential (Eh) gives a value for reducing and oxidizing conditions. The Eh is above 200 mV when soils are in general (sub-) oxidized, and below 0 mV when they are reduced (Fiedler, et al., 2007). The phreatic water table was measured on one location in each measurement station. Precipitation and air temperature was measured at three locations evenly spread (Table 3).

Monitoring results

Groundwater tables at all peatmounds show an increase in time. Average phreatic water table increased on average 18 cm (from -46 cm to -28 cm from surface).

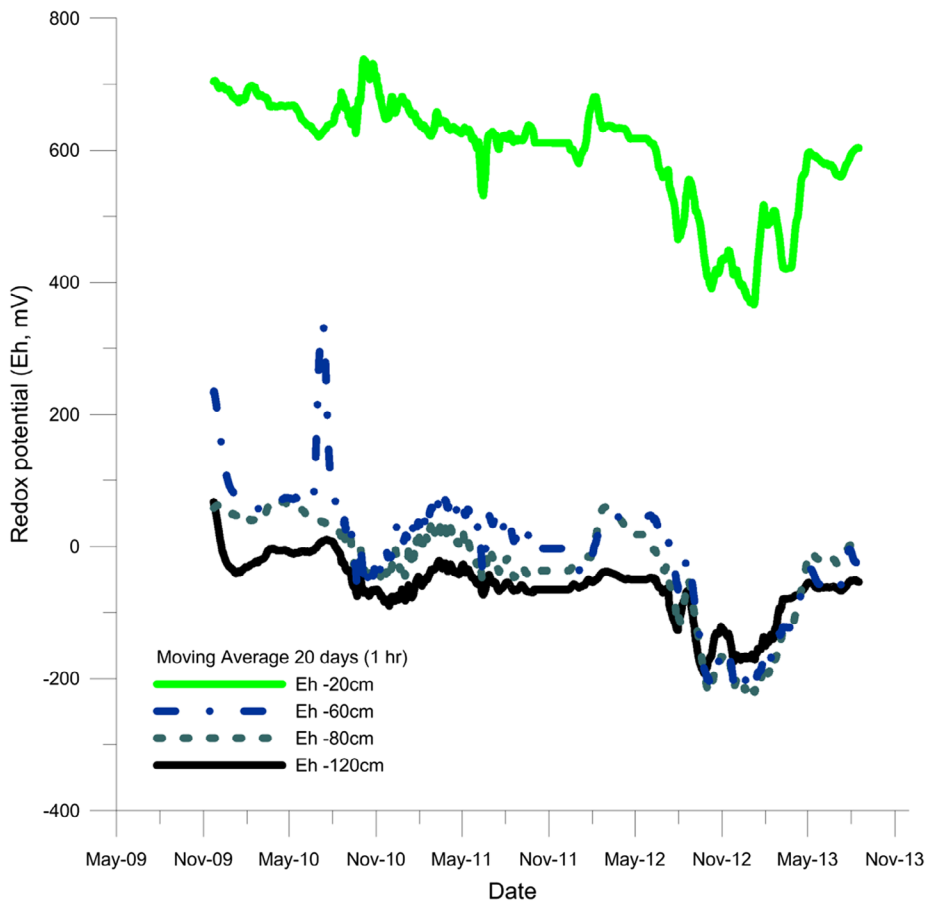


FIGURE 3 Redox potential (Eh) throughout several years in peatmound 84-54.

Looking at one peatmound in particular, 84-54 in the Western National listed Monument, a small but clear effect of the rewetting can be seen. The redox potential in the peatmound, shown in Figure 3, decreased at all measured depths during the first wet winter of 2012-13, and came back to a lower level in summer 2013 than in the other summers. The level at -60 cm is also less variable. The Eh at all but -20 cm from surface are at reduced levels (<0 mV).

Discussion

The aim of the five-year monitoring was twofold. First, the actual conditions at a selection of peatmounds was to be monitored, and those stations would function as a representative sample from the three groups of peatmounds created, thus delivering data for the complete Onlanden area. Second, the results of the first-phase monitoring acted as an offset, to compare to the other measurements performed in the area. The nature organizations managing the site, together with the water authorities, have installed their own equipment to measure various aspects of the functioning of the water storage as a whole. These measurements include water levels in the waterways, and spot measurements of phreatic water pressure. If the trends found in the monitoring results at the peatmounds did not differ from the trends found at the permanent stations installed by the water authorities, then there would be no need to continue those measurements at the peatmounds themselves in the archaeological monitoring. This will greatly reduce the cost for the continued archaeological monitoring.



FIGURE 4 Compressed soil after removal of plastic cover and earthen load in February 2011.

Mitigation

One of the threats to the archaeological value in the peatmounds that was perceived to be of high risk was the future deep rooting of plant species such as common reed (*Phragmites* spp.). These wetland species are known for their high density of roots. As the groundwater table will rise, the peatmounds will act as higher and drier areas, favouring the growth of these species, and thus increasing the risk of root ingrowth. One solution that was proposed was the use of a thick membrane (high density polyethylene, HDPE) to cover the complete mound. This membrane is a 2 mm thick industrial plastic, used in managing waste dumps (Müller, 2007). These covers are guaranteed to be root resistant for fifty years by the supplier, but only if they are protected from UV light/sunlight and larger temperature fluctuations. Therefore, a cover layer of soil on top of this plastic is required. The additional pressure caused by this soil column can however cause a sinking of the farm mound into the soft peat soil below. The risks coming from this protective measure were discussed, and an experimental setup was designed to study the effects for a year. An area of 18 × 18 m was covered in the winter of 2010; the experiment lasted till February 2011 (Figure 4). Redox potential, temperature, and pressure were measured

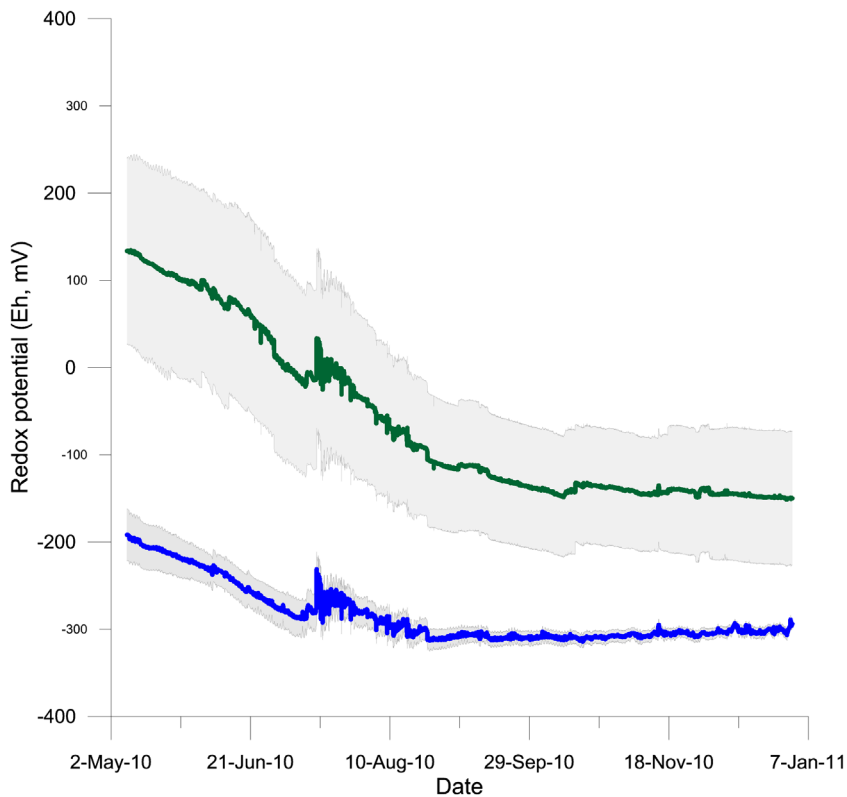


FIGURE 5 Average redox potential ($n = 12$) measured at 5 cm (top, green) and 12 cm (lower line, blue) below surface, with standard deviation in time.

under the cover, and absolute levelling of the plastic cover was performed using settlement plates (See <http://www.dot.state.mn.us/materials/manuals/geotechnical/Appendix%20G%20Installing%20and%20use%20of%20Settlement%20Plates.pdf>). Results (Houthuesen, 2011; Vorenhout, 2008a) showed a steady and reduced soil environment under the cover (Figure 5). Settling was measured, but analysis indicated that only local compression in a vertical direction occurred. The settling was evenly distributed in the horizontal plane (details and discussion in Houthuesen, 2011). Therefore the deformation of the archaeology would be rather minimal: the readability of the profile will still be sufficient as all layers will still be present. The translocation of larger artefacts from one stratum to another will however occur. Items such as bricks will be compressed less than the softer soil surrounding them, and thus be moved upwards. This problem is however a limited problem, as most artefacts found in the test pits were relatively small (data in Nikolay, *in prep.*).

A large potential threat to the archaeology came from the movement of machines in the direct surrounding of the mound. This movement could potentially cause great

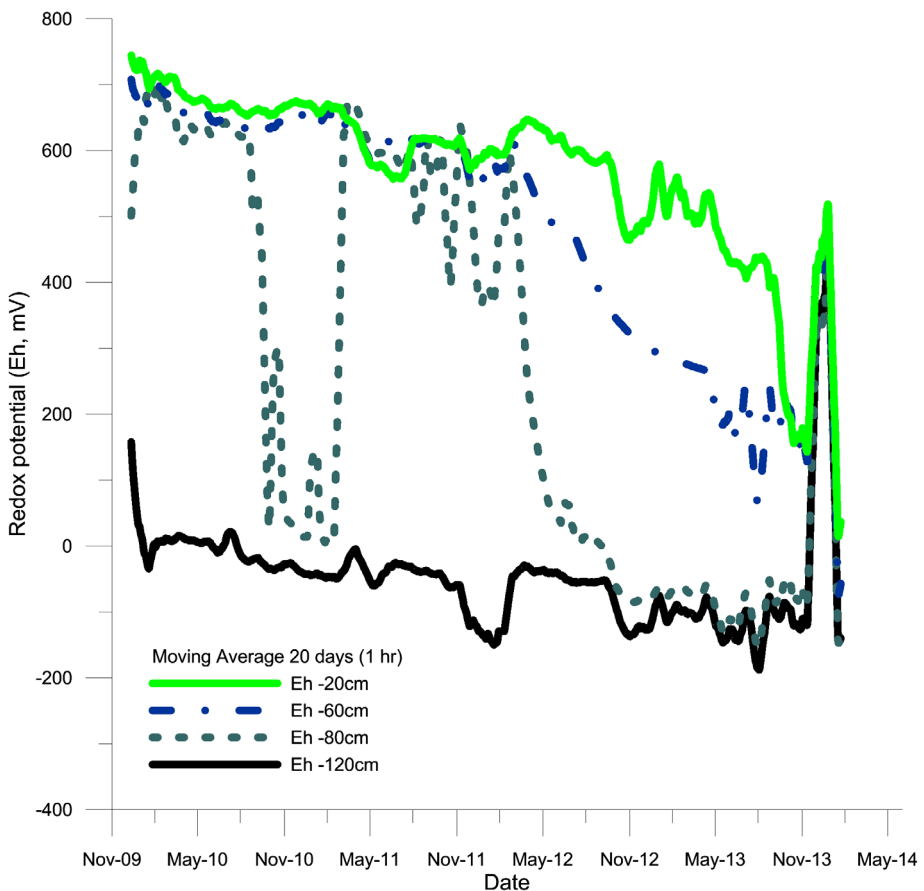


FIGURE 6 Redox potential in a peatmound 19. This mound was covered with plastic and earthen load in 2012.

damage to the topsoil. The cover method was adopted as a protective strategy, given the constraint on cost and the need to reduce surficial damage caused by the machines.

Given the cost of this cover method, only a selection of eight peatmounds could be covered (Houthuesen, 2013). An additional advantage to the selection was that there was no single method of mitigation chosen, spreading the risk on the long term. The effects on redox potential in peatmound 19 (covered in spring 2012) are similar to the effects in the experimental setup: decreased Eh in time starting after coverage, and somewhat reduced variability of Eh (Figure 6). The spike at December 2013 is probably caused by temporary reference probe failure.

Conclusions

The conservation of peatmounds in a water storage area is a challenge. The physical preservation might be possible, but the actual management of the preservation and the number of different disciplines that are involved make it a large and intensive project. Environmental monitoring at the peatmounds themselves shows slowly improving conditions, but the increase of deep rooting plant species at several peatmounds remains an important threat. It is important however to note that the continuation of the original land use would also have put a lot of stress on the preservation of the peatmounds. Continued desiccation, slow but steady physical disturbance by machines, grazing and ditch management, and lack of funding for research are amongst the threats that would for certain have damaged the archaeological archive as well, and possibly much more severely than the current wetland with its reducing conditions ever can.

The deeper sites along the Matsloot are hardly influenced by the current wetland conditions, and probably would have been safe anyway in the old dry conditions.

The applied risk assessment that takes a zero impact scenario into account and uses a stepped approach to come to parameters that can actually be measured, proved useful. It helped in defining a sound monitoring strategy, and aided in the discussions with authorities on the theme of archaeological preservation. The usual set of parameters used in monitoring schemes can be used more appropriately. The final number of monitoring stations was a trade-off between costs and a scientifically sound research approach.

A good lesson learned from this project is that the typology of the peatmounds differed per subarea, and this was not revealed during the initial coring campaign (Schepers, 2008). This lack of insight influenced significantly the design of the monitoring of the physical environment. In retrospect, it would have been better to have a good layer description via a test pit at each mound — as we have available now — and have a clear description of depth of organic and inorganic archaeological layers. This would have reduced the number of shallow measurements, and improved accuracy of measurements, as the monitored depths would have been more specific.

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Notes on contributor

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