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Selection of real-life analogues for future lakes and mires at a repository site

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Abstract. In Finland, Olkiluoto Island on the western coast has been selected as a repository site for spent nuclear fuel. Due to the shallow sea areas around the island, the postglacial land uplift is going to change the landscape within the next millennia. For instance, new lakes and mires will develop on the present offshore areas. Concerning radionuclide transport models, the properties of the future ecosystems surrounding Olkiluoto Island can be forecast based on the properties of present lakes and mires. Due to the lack of site-specific data, lakes and mires of various successional stages were selected within a larger geographical area as analogues of the future ones. Here we present an example of a systematic process for selection of appropriate analogue sites.

1. INTRODUCTION

Posiva Oy is responsible for implementing a repository programme for spent nuclear fuel from the Finnish nuclear power reactors currently in operation and under construction. The spent nuclear fuel is planned to be disposed of in a deep geological repository located on Olkiluoto Island, which is situated in the municipality of Eurajoki on the Finnish coast of the Baltic Sea. To address the long term safety requirements, Posiva Oy is compiling a Safety Case Portfolio [1]. One factor to be taken into account in the safety analyses is the postglacial land uplift (approximately 6–6.8 mm/y [2, 3]), which affects the hydrogeochemical and biological systems of Olkiluoto and its surroundings. Also, new lakes and mires will develop on the present sea areas (Fig. 1) during the next millennia, and their properties will continue to change due to further increase in the position above sea level and physical, chemical and biological processes going on in the objects themselves and their catchments.

The properties of the future lake and mire ecosystems surrounding Olkiluoto Island can be forecast and radionuclide transport models applied based on the properties of present lakes and mires. Currently, however, there are no lakes and only a few mires on the island. The existing mires are small and young, and thus can give only a weak basis for the forecasts of future landscapes.

Due to the lack of site-specific data in the long-term context, a project was initiated, where lakes and mires of various successional stages were selected within a larger geographical area as analogues of those expected to form at the Olkiluoto site. An intersection of good analogue sites and those with plenty of study results was searched for. The project and detailed results have been presented by Haapanen et al. [4], and here the systematic process for selection of analogue sites, appropriate to the multi-millennial site-specific assessment context, is illustrated.

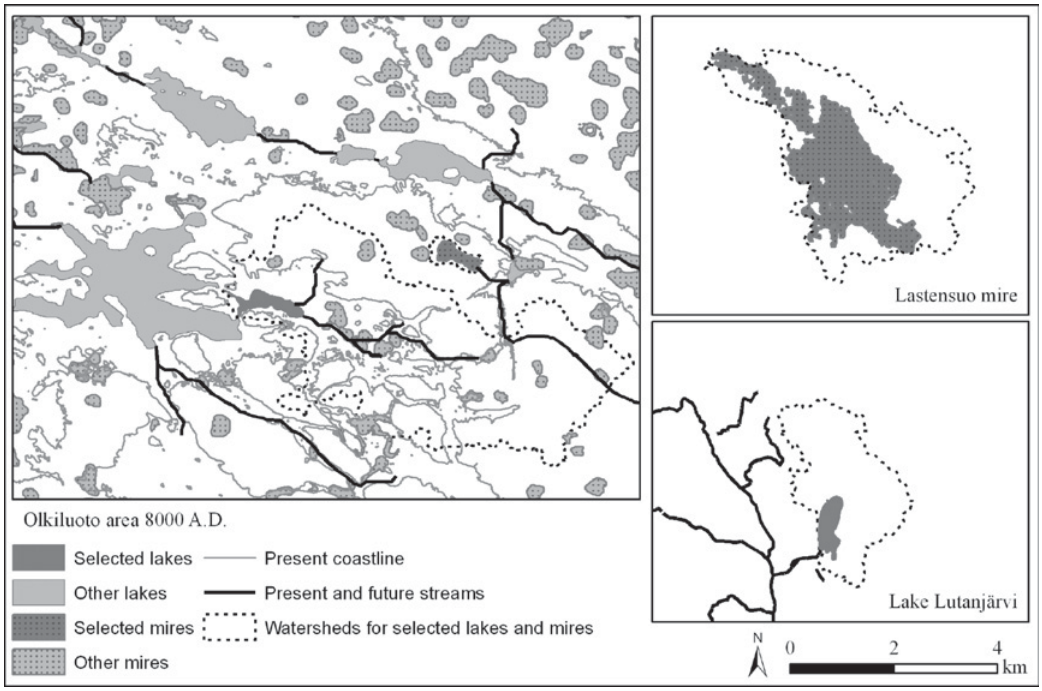

Figure 1. Main future lakes and mires developing during the next 8000 years in the present sea areas around the Olkiluoto repository site [5, 6]. Examples of analogues for future lakes and mires are shown on the right side: Lastensuo mire and Lake Lutanjärvi. Background map: topographic database by the National Land Survey of Finland (permission no. 41/MYY/11), derivation of catchments based on these data, as well. Map layout by Jani Helin/Posiva Oy.

2. MATERIAL AND METHODS

The selected analogue sites should be as similar as possible to the sites which will develop in the future at Olkiluoto area. Geological, biological and climatic properties and their historical development limited the search area into Southwestern Finland. Within the defined search area, the following parameters were considered most important:

- Size and shape (in case of mires these may be altered during time due to peat accumulation and mire expansion)
- Size and soil properties of the catchment area
- Degree of human impact
- Nutrient level of water or peat
- Distance from coastline (correlates with object age and the phase of the Baltic Sea after the Weichselian glaciation)
- For lakes: drainage type (drainage lake/headwater lake/closed lake)
- For mires: origin (primary mire formation, lake terrestrialization, paludification of mineral soils)

Some of these properties could be estimated via GIS analyses [5, 6], literature and expert knowledge. The lakes predicted to develop in the nearby areas of Olkiluoto Island are a lake chain, a small lake and an overgrown lake, all very shallow (mean depth ca. 1–5 m) already at the beginning, with areas between 10 and 800 ha.

Predicting future mire properties is even more demanding than lakes, since, in addition to topographic and edaphic factors, climate plays a large role in the development of a mire, from initiation

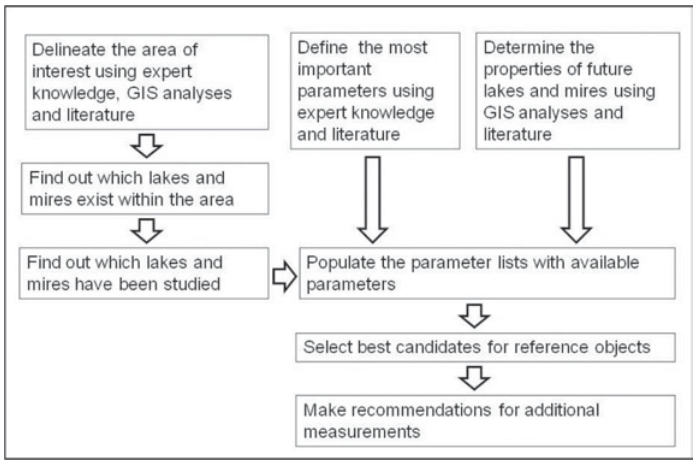

Figure 2. Steps taken in the process of selecting real-life analogues for future lakes and mires in the Olkiluoto repository area.

to the later development stages. According to Ikonen et al. [5, 6], the future mires will originally cover small areas and situate mainly on till soils and clays. A large variation of shapes is to be expected. It was decided to go for a very young mire, a young mire, an old and small mire and an old and large mire in the search of analogues.

For the existing lakes and mires, data sources included literature, environmental databases and generic GIS data. Several licences were acquired for GIS data and databases, to be used also in other studies in the repository programme. Some data were used at the metadata-level only in the selection process. A generalization of the selection process is presented in Fig. 2.

3. RESULTS AND DISCUSSION

In the process, 27 lakes and 33 mires were selected. The characteristics of these objects were presented in a standardized format and literature lists were completed. Then, a smaller sub-set of 11 lakes and 11 mires was selected for a closer look: catchments were calculated and maps showing their extent, the extent of the watershed, the surrounding topography, soil types and major landscape elements were drawn. Finally, 7 lakes and 4 mires were presented in the Olkiluoto Biosphere Description 2009 [7]. The properties are presented in Tables 1–3.

During the review and selection process, it was confirmed that the following issues cause uncertainty in the applicability of the information on analogue sites:

- Human actions have changed majority of the lakes and mires in Southwestern Finland.
- The properties of future lakes and mires nearby Olkiluoto are based on GIS analyses with partly inaccurate data and many assumptions, e.g. climate change may change the picture.
- Any object cannot be an exact analogue to another, even less to a ecosystem object predicted to form long in the future; a multitude of factors affect to the state of the objects and usually only a rather limited set of parameters have been studied together.
- Lakes with most data are typically large lakes or lakes that have had problems in their condition. Similarly, the economically focused peat surveys cover only large mires. Thus the selection among small-sized lakes and mires was very random.
- Parameters available for lakes and mires depend on the emphasis of the studies carried out on them. Further, the monitoring periods vary from a single survey to long-term studies, and the spatial sampling densities from one survey point to a dense grid of measurements.

Table 1. Central properties of the present lakes selected for the analogues of the forecast future lakes near Olkiluoto. References can be found in [7].

	Valkjärvi	Poosjärvi	Kivijärvi	Lampin -järvi	Koskeljärvi	Suomenperän -järvi	Lutanjärvi
Size, ha	335	350	53	82	657	122	40
Shape	Oblong	Oblong	Hourglass	Oblong	Complex	Round	Oblong
Elevation, m a.s.l.	51	31	25	21	42	41	14
Depth mean (max), m	2.9 (5.2)	1.6 (-)			1.2 (3.2)		1.6 (6.5)
Volume, m^3	9,647,000	5,600,000			7,383,000		640,000
Catchment, km^2	12.3	31.8	36.6	12.9	65.0	14.2	5.0
Shoreline, km	17.5	36.8	9.4	11.7	31	11.3	3.3
Water delay	2.5–3.5 y				200 d		3.2 y
Drainage type	Headwater	Drainage			Drainage	Drainage	Headwater
Land cover in catchment	Till and rock forests	Till and rock forests	Till forests, mires	Till forests, mires	Till and rock forests, mires		Till and rock forests, clay fields
Represents	Medium-sized	Lake chain			Overgrowing		Small

Table 2. Water quality of the present lakes selected for the analogues of the forecast future lakes near Olkiluoto during winter and the open-water season in 2000–2008. References can be found in [7].

	Valkjärvi	Poosjärvi	Kivijärvi	Lampinjärvi	Koskeljärvi	Lutanjärvi
Total P, μg/l	18	56	45	43	18	12
Total N, μg/l	484	733	690	700	552	650
Chlorophyll-a, μg/l	13	16	13	18	6	
pH	7.0	6.6	6.7	6.9	6.8	7.5
Colour, mg_{Pt}/L	28	120	140	145	62	
Oxygen, %	96	83	81	94	96	90

- Availability and organization of information differed between lakes and mires, and the situation was better in the case of lakes due to a greater amount of uses (water reservoirs, hydropower, irrigation, fishing, recreation and flood control) and larger public interest.
- The administrational borders are problematic when compiling data over a large area. Moreover, changes in these borders make comparisons over time very difficult.
- Preparation of mire data for GIS analyses was laborious due to differing naming conventions, inaccurate locations, similar mire names occurring in several municipalities etc.

4. CONCLUSIONS

At Olkiluoto, the post-glacial land uplift changes the landscape from a coastal island to an inland site within some millennia – i.e. by the time the earliest releases are expected to be able to reach the biosphere from the repository deep in the crystalline bedrock. New lakes and mires will form in the present offshore area. Despite the lack of lakes and well-developed mires at present Olkiluoto Island, input data for models, appropriate to the site-specific context are required for the repository licensing assessments. Therefore, we set out for finding analogue objects in a larger geographical area. Based on the collected data, formulation of scenarios on future human actions is also on a sounder basis; the human actions have had an important role in modifying the conditions of lakes and mires in Finland.

Table 3. Central properties of the present mires selected for the analogues of the forecast future lakes near Olkiluoto. Peat types: S = *Sphagnum*, C = *Carex*. References can be found in [7].

	Pesänsuo	Lastensuo	Kontolanrahka	Olkiluodonjärvi
Size, ha	18	440	880	12
Shape	Round	Ellipsoid with 2 centres	Round	Unclear
Origin	Primary mire formation, paludification	Not known	Paludification, expansion	Primary mire formation, terrestrialization, paludification
Bottom soil	Clay	Clay, sand	Clay	Gyttja clay, clay, sand, till
Elevation, m a.s.l.	80–87	44–48	80–86	1.5
Age, yrs	9200	5300	9,400	500
Peat thickness mean (max), m	(6.7)	(6.3)	5 (7.1)	1.6
Catchment, km^2	0.2	11	12.4	
Description	Forested	Open in the centres	Treeless and forested parts	Treeless and forested parts
Peat types, % of volume	S 80, C 20	C	S 88, C 12	S, C
Land cover in catchment	Fields	Till forests	Clay fields, till forests	Till forests, small fallows

Even though no analogue can ever be perfect, this is a more reasonable approach compared with constructing arbitrary sets of possibly internally inconsistent parameter values for the models. Concerning the need of specific parameters, there is now a possibility to complement the parameter sets with new investigations targeted on the analogue sites. Thus, after the selection process, aerial photographs have been taken, and supplementary field inventories, GIS analyses, and collection and analyses of flora, fauna and soil/peat samples have been carried out. Interdisciplinary interpretation of the collected data is going on.

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