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THE WATER QUALITY OF THE TWO MAARSSEVEEN LAKES IN RELATION TO THEIR HYDRODYNAMICS

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KEYWORDS : Maarsseveen Lakes; trace metals; water quality; hydrodynamics.

ABSTRACT

The hydrodynamics of the two Maarsseveen Lakes are the main cause of the difference in water quality. The meso-oligotrophic Lake I is mainly supplied by groundwater and rainwater while the eutrophic Lake II is fed by water from the River Vecht. Both lakes, however, have a relative high concentration of Zn and Cd in their water system and sediment. The mean concentrations of Zn and Cd in the water system are even higher than in the River Vecht. Measurements of atmospheric deposition (dry and wet) illustrated high levels of Zn, Cd and Cu transported to this area. There are indications that three metallurgical industries located in this region are responsible for the high deposition of these metals in the lakes (PULLES, 1986).

INTRODUCTION

The two Maarsseveen Lakes are situated to the north and west of the city of Utrecht (Fig. 1). In former times, the area was part of an extensive region of swamps where peat was dug, leaving a variety of pools and shallow lakes (KAL *et al.*, 1984). The Loosdrecht Lakes (Fig. 1), for example, are shallow lakes originating from these peat-digging activities. Some of the lakes and pools in this region have been drained to produce polders, *e.g.*, the Bethune Polder. These areas of recently formed land are now used for agriculture. Still other former peat harvesting sites have been used for excavation of sand, leaving deep lakes, *e.g.*, Maarsseveen Lakes. There are, however, still some nutrient-poor landscape elements left, like swamps, floating fens and hay-fields (BELTMAN *et al.*, 1986). Because of anthropogenic alterations and additional groundwater extractions for drinking water, the hydrodynamics of this area have been changed. In former times, the area was supplied chiefly by groundwater and rainwater. The origin of most of the groundwater is rainwater falling on Pleistocene dunes in the east ('Utrechtse Heuvelrug') and seeping through the bottom. Upward seepage (water-flow from the first aquifer to the surface) occurs where the water pressure in the first aquifer is higher than the surface water level (DE VRIES, 1980).

Currently, water from the 'polluted' river Vecht is taken in during summer to keep up the level of water in canals and ditches for agricultural purposes (Fig. 1). A small part of the area is still supplied solely by groundwater and rainwater.

In order to obtain additional information about the relationship between the hydrodynamics and the water quality of the Maarsseveen Lakes, a study has been initiated by the Provincial Water Board of Utrecht.

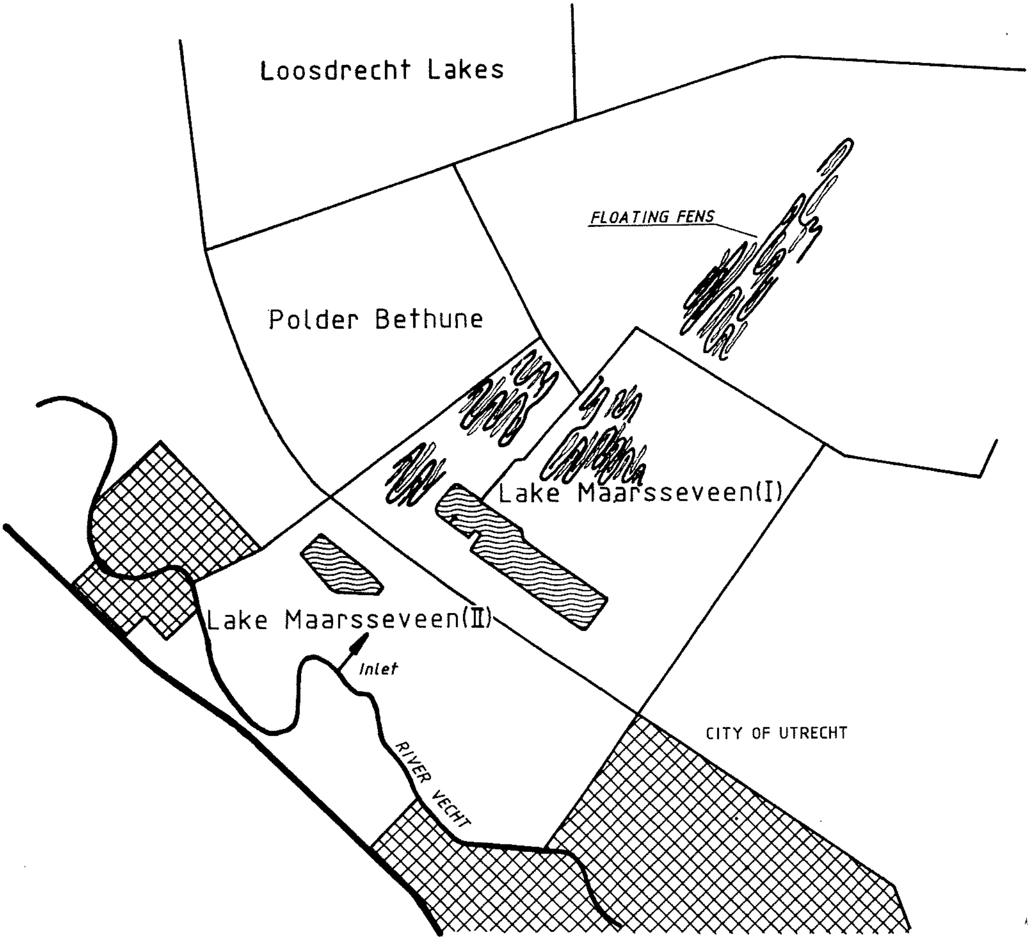

Fig. 1. Maarsseveen Lakes area.

METHODS

A program for measuring water quantity and water quality was established by the Provincial Water Board in cooperation with the ICW (Institute for Land and Water Management Research). Piezometers were placed to measure piezometric levels of the groundwater of the first aquifer. Additional measurements were made of the levels of standing surface water. These levels were read bi-weekly, and monthly samples were taken for chemical analysis of the surface water.

The chloride content of the surface water was regularly measured to define the region in which the surface water is influenced by the intake of water from the River Vecht.

Samples of rainwater were taken over a period of three months to determine the deposition (dry and wet) of selected heavy metal contaminants (Fig. 5). Data on the quality of the groundwater of the first aquifer were found in literature (WASSEN, 1986). Further heavy metal analyses were carried out on the sediment with a Jenkins mud-sampler in the center and on the shore of the lakes.

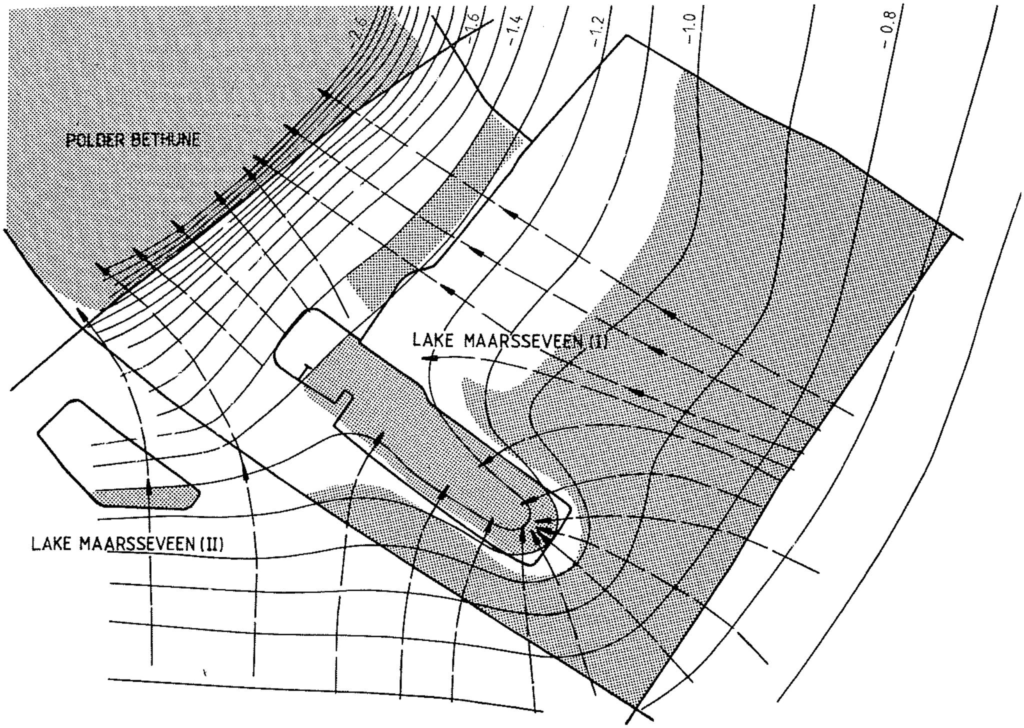

Fig. 2. Piezometric levels of the first aquifer and flow of groundwater within this aquifer. Areas of potential groundwater seepage (shaded) in October 1985 are given.

RESULTS

The plot of 1985 isohypses demonstrates a flow of groundwater in north-west direction (Fig. 2). The flow is perpendicular to the isohypses going from high to low piezometric levels (DE VRIES, 1980). The low-lying Bethune Polder and Lake Maarsseveen I are the main sinks for the groundwater. The shaded regions of Fig. 2 indicate the potential areas where seepage to Lake Maarsseveen I may have occurred in October, 1985. This is an example of a wet period. During the dry summer periods, the shaded areas are smaller, retreating to the east. These results are given in WIT *et al.* (1987). For Lake Maarsseveen I, a total upwelling seepage of 400.000 $m^3.year^{-1}$ was determined, and for the Bethune Polder, 33×10^6 $m^3.year^{-1}$ was found. In the Bethune Polder, a continuous drainage of superfluous water is necessary to control the polder water level. A great amount of this water from the Bethune Polder is used as drinking water for the city of Amsterdam. Surface water infiltrates in the unshaded areas of Fig. 2, and in dry periods water from the River Vecht may enter.

Before water from the River Vecht can reach Lake Maarsseveen I, it must first pass through Lake Maarsseveen II, and an area of narrow canals and strips of boggy land called the 'Zodden' (Fig. 3). Regular chloride measurements in this 'Zodden' area during the summertime demonstrate that water from the River Vecht does not reach Lake I. Chloride concentrations in the 'Zodden' measured by the Department of Aquatic Ecology of the University of Amsterdam in august 1985 are given in Fig. 4. In this area, infiltration to the Bethune Polder occurs. Thus, Lake I is mainly supplied by groundwater and rainwater while Lake II is fed by water from the River Vecht.

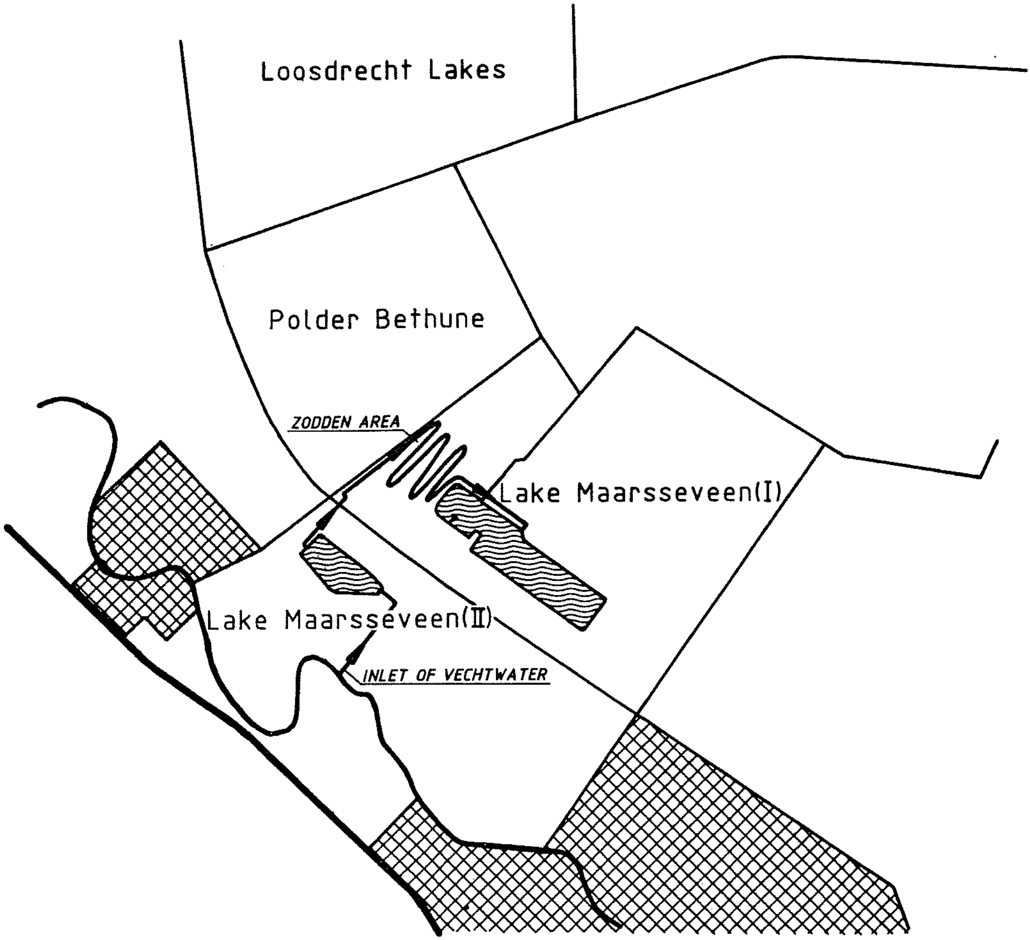

Fig. 3. Direction of water flow from the River Vecht in the lakes area.

The mean values of the most important chemical parameters of the different water sources are given in Table 1. There is a striking resemblance in water quality between the River Vecht and Lake II (high concentrations of tP, Cl, Na, NO_3, and SO_4), and seepage water and Lake I (low concentrations of tP, Cl, Na, NO_3 and SO_4).

For the trace metals Zn and Cd, however, the concentrations in the surface water of both lakes are higher than the values in the River Vecht. Measurements of the metal deposition in the area suggests a two to three fold increase in deposition (dry and wet) for Zn and Cd compared with De Bilt, a meteorological station to the east of the city of Utrecht (Table 2 and Fig. 5). The resulting concentrations of Cd, Zn and Cu in the sediments of the two Maarsseveen Lakes are presented in Table 3.

Lake Maarsseveen II, supplied by both water from the River Vecht and by precipitation, had higher levels of the three metals in the sediments than were observed in Lake Maarsseveen I, supplied primarily by precipitation and seepage. The levels of these metals are higher in the center of the lake systems than in the nearshore sediments. This is undoubtedly caused by the fact that deposition of sedimentary materials, with a high binding capacity for trace metals, takes place in the deepest (central) part of the lakes.

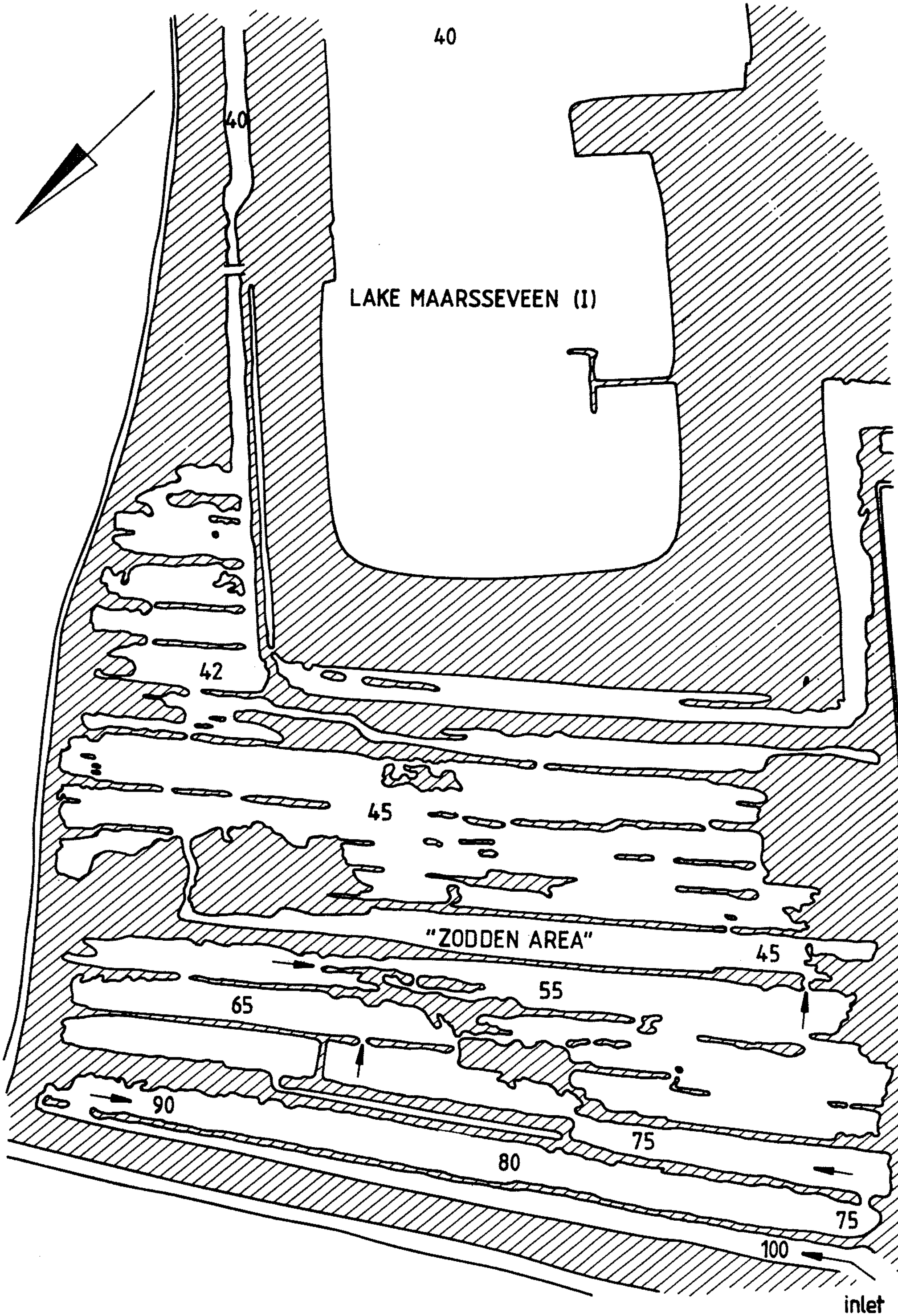

Fig. 4. Chloride concentrations in the 'Zodden' area in $mg.l^{-1}$ (August, 1985).

Mean conc. 1984/1985		River Vecht	Seepage water from the first aquifer	Rainwater		Lake Maars-seveen I	Lake Maars-seveen II
				Maars-seveen Lakes	De Bilt		
Na	$mg.l^{-1}$	100.0	8.0		2.8	17.0	60.0
Cl	$mg.l^{-1}$	145.0	17.0		4.5	36.0	90.0
t.P	$mg.l^{-1}$	1.4	0.2	0.05	0.05	0.02	1.1
NO_3	$mg.l^{-1}$	21.0	1.2		5.5	0.5	8.6
NH_4	$mg.l^{-1}$	5.0	2.0		3.1	0.2	0.9
SO_4	$mg.l^{-1}$	90.0	10.0		9.6	17.0	55.0
t.Zn	$\mu g.l^{-1}$	46.0	< 10.0	115.0	62.0	137.0	81.0
t.Cu	$\mu g.l^{-1}$	6.3	< 1.0	7.7	5.8	1.5	2.2
t.Cd	$\mu g.l^{-1}$	0.3	< 0.1	1.5	0.3	1.2	0.4
t.Ni	$\mu g.l^{-1}$	5.6	< 1.0		1.9	0.8	2.1
t.Pb	$\mu g.l^{-1}$	7.8	< 1.0		18.0	< 1.0	< 1.0

Table 1. Mean values of the most important chemical parameters characteristic of the various water sources.

Sample station	Annual precipitation in mm	Total annual deposition in $mg.m^{-2}.year^{-1}$		
		Cd	Cu	Zn
I	784	0.816	4.785	54.122
II	692	0.756	2.766	45.331
III	606	0.562	3.551	31.946
IV	682	0.604	2.500	41.578
V	699	0.833	6.370	53.873

Table 2. Wet and dry deposition of Zn, Cu and Cd at 5 sampling stations; sample locations are shown in Fig. 5. Measurements over a three month period are converted to a period of a year. The background deposition of Cd, Cu and Zn was 0.225, 2.222 and 15.589 $mg.m^{-2}.year^{-1}$, resp.

DISCUSSION

The hydrodynamics of the two lakes are the main cause of the difference in water quality. Lake Maarsseveen I is not supplied by water from the River Vecht, but rather, is seepage water controlled with the direction of water flow towards the Bethune Polder (Fig. 2). Lake Maarsseveen I is meso-oligotrophic, and Lake Maarsseveen II eutrophic. Both lakes, however, have a relative high content of Zn and Cd. The mean concentrations in water systems are even higher than in the River Vecht. Measurements of atmospheric deposition (dry and wet) illustrated the high levels of Zn, Cd and Cu transported to this area. There are indications that three metallurgical industries located in this region are responsible for the high deposition of these metals in the lake (PULLES, 1986). However, the concentrations of Cd, Zn and Cu in the Maarsseveen Lakes are not so high that acute toxic effects are to be expected (MOORE and RAMAMOORTHY, 1983).

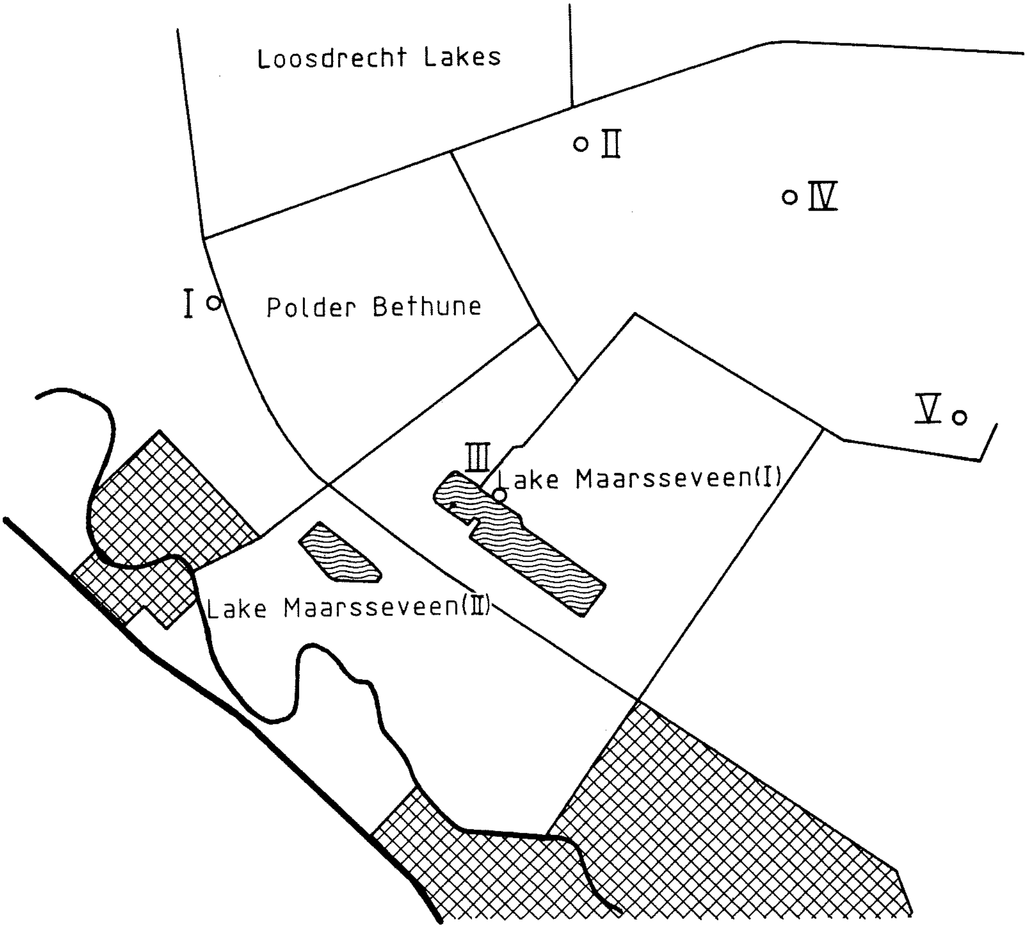

Fig. 5. Sampling stations of deposition (wet and dry).

Trace element	Date	Lake Maarsseveen I		Lake Maarsseveen II	
		Shore	Center	Shore	Center
	Feb. 1984	0.5	1.1	1.1	6.0
Cd	Nov. 1984	1.2	3.2	2.0	3.5
	Apr. 1986	1.0	1.3	1.0	5.5
	Feb. 1984	36.0	230.0	257.0	1080.0
Zn	Nov. 1984	118.0	220.0	190.0	816.0
	Apr. 1986	27.0	173.0	140.0	480.0
	Feb. 1984	7.0	39.0	35.0	137.0
Cu	Nov. 1984	20.0	37.0	20.0	95.0
	Apr. 1986	6.0	32.0	30.0	119.0

Table 3. Sedimentary concentrations of selected trace elements in Lake

Further research is necessary to provide a clearer understanding of the origin of the trace elements, and to examine the potential effects of these metals on the aquatic ecosystem. Consideration should be given to remove the direct connection between the River Vecht and Lake Maarsseveen II. This would eleminate the high P concentrations which are apparently responsible for the algal blooms in this lake during the summer. It may be possible to use seepage water from the Bethune Polder or water from the Loosdrecht Lakes to replace the inlet water from the River Vecht. Further studies on possible alterations of water supply to this area are being undertaken by the Provincial Water Board in cooperation with the Institute of Land and Water Management Research.

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