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SALT WATER CONTAMINATION OF THE WELLS ALONG THE BARNAART-SCHUSTER CANAL in the Amsterdam Dune Water Catchment Area (South of the City of Haarlem). 2 figures.

1. Introduction

At the meeting, held at Vogelenzang on May 13 - 15, 1970, a survey was given of dune water extraction and the salt water encroachment problem involved. For a more detailed description, see Lit. (1) *). In the following, a special case of salt water encroachment will be considered, as it occurs in 32 wells situated along the Barnaart-Schuster Canal, in the central part of the catchment area (Fig. 1). The row of wells runs parallel to the North Sea coast, at a distance of 1800 meters. The wells are located at intervals of 100 meters.

Water is extracted from the so-called lower aquifer, a semi-confined aquifer located between 20 and 160 m - O.D.

The wells are screened in the upper section of the aquifer, at depths between 25 and 35 m - O.D. with a view to salt water encroachment from the lower strata.

The 32 wells are linked by a horizontal pipe-system, through which water is extracted simultaneously from all the wells by means of a vacuum pump. Together, the wells yield about 8000 m3 daily, i.e. an average production of 10.4 m3 per well, per hour.

The wells were operated without major interruptions from 1915 until 1957. Total water extraction over that period was about 60 million m3. After the start of artificial recharge of water from the river Rhine in 1957, the wells have been only sporadically used.

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*) Literature listed at the end of this article under (1).

2. Geohydrological situation

The aquifer is sealed off from the overlying strata by a clay-layer, which offers a - locally strongly varying - resistance to vertical waterflow. The geological data obtained from test-bores give no indication as to the nominal or relative values of this resistance.

Fig. 1 also shows the location of the deep observation wells that reach down into the salt water area underlying the fresh water in this same aquifer. The observation wells go to a depth of about 120 m - O.D. Groundwater with a Cl' concentration of more than 10,000 p.p.m. is found below a level of abt. - 100 m - O.D.

In some places the lower aquifer is divided into two subaquifers by the so-called loam-layer; a stratum of varying thickness, which is present in the area of observation wells 27, 246, 190 and 33 at depths of between 60 and 90 m - O.D. No sign of this layer was found in bores 255 and 247 (location, see Fig. 1). Pumping tests and groundwater analyses have proved that the loam-layer is to some degree impervious to groundwater flow.
For the upper aquifer, between 6 m + and 15 m - O.D., a system of artificial recharge with Rhine-water has been in operation since 1957. The Cl' concentration of this Rhine-water seldom drops below 100 p.p.m. Before 1957, the upper aquifer contained original dune water, which, like the present stock of fresh water in the lower aquifer, had a Cl' concentration of about 30 p.p.m. The groundwater head over the clay-layer has always been higher than that at the deeper levels of water extraction.

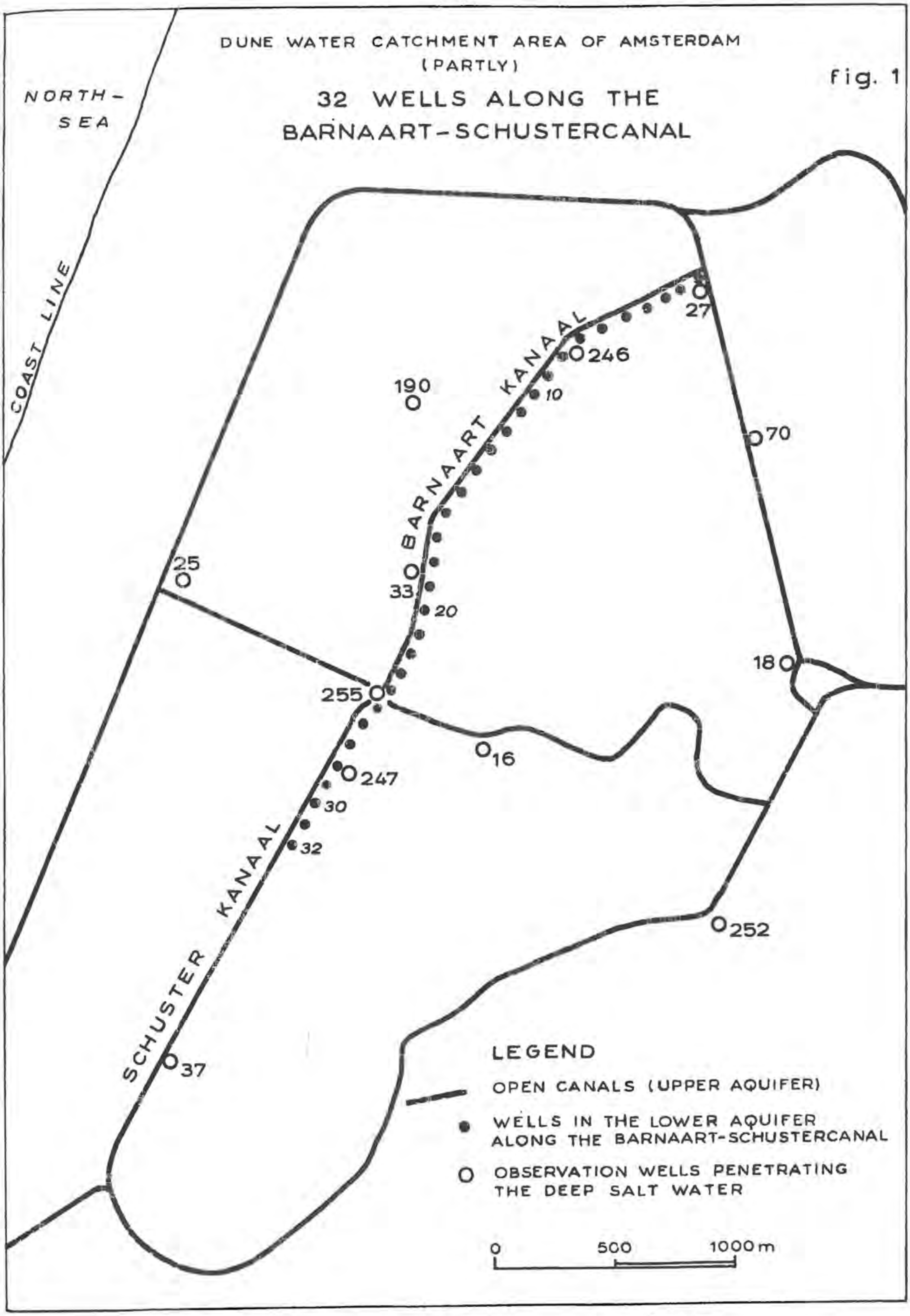
3. Inversion of the Cl' concentration

Analyses of the Cl' concentration in the waterwells have been conducted at regular intervals. The results for the period 1939 - 1972 are listed in Fig. 2. Concentrations higher than 40 p.p.m. are indicated by the darkened sections. A distinction must be made between the years prior to the start of artificial recharge, in 1957, and the subsequent period. The wells which had increased Cl' levels before 1957 appear to have returned to normal after 1957, and vice versa. At first sight, this seemed a remarkable case of inversion. For an explanation of the phenomena involved, three different zones are introduced, as in Fig. 2.

Initial observation shows that in zone 1, there is a well-developed loam-layer, capable of resisting vertical water-flow. This will prevent salt water contamination of the wells, even during periods of continuous water extraction. No loam-layer is present in zone 2, where intensive extraction will entail increased Cl' concentrations in the wells. The increase is caused by cones of brackish water, rising from the underlying salt water. Zone 3, like 2, has no loam-layer, but despite this, no salt water contamination occurs. Apparently, other factors are at work here. This becomes clear if we look at the results of the analyses carried out after 1957. In the first place, it may be observed that the wells in zone 2 present the normal picture, viz. a shifting of the brackish water cones after extraction is stopped, and the return of original, fresh dune water in the wells. Next, it was found that, since the start of river water infiltration, the water in the upper aquifer in the B.S. Canal area has had a Cl' concentration generally higher than 100 p.p.m. After 1957, little water has been extracted from the lower aquifer and therefore the increased Cl' concentration in zones 1 and 3 must be the result of river water infiltration into the lower aquifer. In zone 2, the resistance to vertical waterflow of the clay-layer apparently (still) suffices to prevent the river water from penetrating downward. The fact that in zone 3, where there is no loam-layer, no salt water intrusion was recorded before 1957, points to a local drop in resistance of the clay-layer, allowing for powerful recharge from the upper aquifer. A "hole" in the clay-layer seems to be the only possible explanation. In zone 1 the absence of salt water encroachment before 1957 may be explained by two factors:

the presence of the loam-layer below the level of water extraction and the permeability of the overlying clay-layer. None of this, of course, would have been possible if not the water level over the clay-layer had been higher than that below. The conclusion seems obvious that the salt water contamination in the wells of zone 2 was determined by the high resistance to vertical flow of the clay-layer. This conclusion is supported by more detailed chemical analysis of the well-water. Research on this subject is continuing.

Lit. 1. Roebert, A.J. Fresh water winning and salt water encroachment in the Amsterdam dune water catchment area, Geologie en Mijnbouw, Vol. 51 (1) p. 35 - 44, 1972.


DUNE WATER CATCHMENT AREA OF AMSTERDAM
(PARTLY)
32 WELLS ALONG THE
BARNAART-SCHUSTERCANAL
fig. 1
NORTH-
SEA
COAST LINE
BARNAART KANAAL
SCHUSTER KANAAL
27
246
190
10
70
25
33
20
18
255
16
247
30
32
252
37
LEGEND
OPEN CANALS (UPPER AQUIFER)
WELLS IN THE LOWER AQUIFER
ALONG THE BARNAART-SCHUSTERCANAL
OBSERVATION WELLS PENETRATING
THE DEEP SALT WATER
0
500
1000 m

Cl'-CONTENT (ppm) OF THE WELLWATER IN THE DEEP AQUIFER ALONG THE BARNAART-SCHUSTERKANAAL (1939 — 1972)

fig. 2

1939 — 1957: PERMANENT DEEP WATER WINNING

NUMBER OF THE WELLS (see fig.1)	7.10 1939	1.12 1941	17.12 1942	4.11 1943	12.10 1944	5.12 1945	18.10 1946	22.1 1948	4.2 1949	12.11 1949	23.1 1950	4.11 1951	9.12 1952	15.1 1954	8.1 1955	22.12 1955	14.4 1957
1	37	33	33	33	34	34	37	38	37	34	—	35	32	32	32	33	34
2	32	33	33	32	28	34	37	35	35	33	—	34	30	31	32	32	34
3	32	35	33	32	32	36	35	34	34	33	—	33	30	33	33	31	34
4	32	34	35	33	32	36	35	34	34	32	—	32	29	32	33	32	34
5	34	35	35	35	35	36	36	35	36	32	—	32	31	29	33	32	35
6	34	35	36	36	35	35	35	36	35	33	—	31	29	30	31	31	34
7	35	33	33	32	33	33	34	33	33	31	—	31	32	29	30	31	33
8	34	34	33	31	32	33	32	33	32	30	—	31	27	31	31	30	33
9	34	34	32	33	34	34	35	33	35	31	—	31	33	30	31	29	31
10	33	31	34	34	35	35	34	34	34	32	—	33	28	30	31	30	31
11	33	30	33	34	36	35	34	34	35	31	—	32	28	30	31	30	31
12	32	32	33	33	34	34	34	35	34	32	—	31	31	31	33	30	32
13	33	28	32	32	34	32	33	34	34	32	—	33	32	32	32	32	33
14	33	28	30	29	31	31	31	—	32	31	—	31	30	31	30	30	32
15	32	29	32	30	31	32	35	31	26	30	—	31	23	30	30	31	33
16	31	32	32	27	33	33	34	32	32	31	—	31	27	30	31	31	30
17	30	31	33	28	32	32	32	31	32	32	—	33	27	34	62	60	82
18	33	30	34	27	35	32	31	35	38	41	44	46	32	54	64	134	117
19	32	29	28	28	42	31	32	39	41	62	69	59	50	48	87	107	118
20	32	32	31	31	46	32	35	41	42	54	—	73	41	42	48	55	63
21	35	33	31	35	36	36	35	34	36	34	—	37	58	35	35	[illegible]	60
22	34	32	26	33	58	38	35	57	59	98	—	145	44	41	58	82	76
23	34	32	34	41	83	34	45	88	71	136	148	166	48	39	78	90	62
24	33	31	33	28	72	33	36	56	54	90	—	105	41	45	93	94	54
25	32	31	34	33	36	34	34	40	48	86	93	118	34	35	55	56	59
26	32	30	30	33	36	35	34	35	38	51	58	74	34	34	62	64	61
27	32	32	30	27	36	34	33	35	37	44	46	85	34	32	36	41	42
28	29	30	35	31	32	31	32	30	31	33	—	38	33	30	31	33	34
29	31	33	31	31	32	33	32	31	30	32	—	36	29	30	31	31	33
30	31	32	27	34	34	33	32	32	32	30	—	35	29	30	32	34	33
31	33	35	34	35	35	36	35	32	34	30	—	30	23	29	33	31	33
32	33	38	35	36	37	37	37	35	38	33	—	31	28	31	34	30	33

IN 1957 BEGAN THE ARTIFICIAL RECHARGE WITH RIVERWATER (> 100 ppm Cl')

1959 — 1972: NO DEEP WATER WINNING; RIVERWATER IS PRESENT ABOVE THE CLAYLAYER

Well	23.2 1959	2.12 1959	24.4 1963	19.3 1970	10.6 1970	10.7 1970	30.7 1970	3.2 1971	17.12 1971	5.12 1972	Zone
1	29	39	31	44	40	42	42	45	49	53	ZONE 1 WELL 1 – 16
2	32	38	34	44	42	41	42	41	45	43	
3	30	34	34	38	36	37	40	37	79	187	
4	35	33	33	48	43	43	43	42	162	—	
5	33	32	38	40	53	54	56	52	122	121	
6	32	34	38	65	51	50	52	48	110	81	
7	24	33	34	43	47	50	55	44	48	43	
8	31	34	35	41	45	47	50	43	50	43	
9	27	32	36	48	53	55	55	51	53	47	
10	27	33	34	54	71	71	67	63	77	81	
11	24	29	34	128	100	66	80	108	129	152	
12	29	28	31	91	72	67	72	83	104	106	
13	29	34	32	92	83	81	87	109	127	132	
14	34	28	30	64	59	61	67	68	—	119	
15	31	33	34	94	75	70	72	82	70	113	
16	—	35	35	—	41	52	43	59	41	105	
17	44	32	34	37	35	36	37	48	38	87	ZONE 2 WELL 17 – 25
18	39	31	30	37	34	33	36	36	32	41	
19	35	31	30	33	45	52	61	37	35	31	
20	32	32	32	35	35	38	43	32	112	28	
21	32	33	31	34	32	32	35	34	43	33	
22	30	30	31	38	32	31	34	34	108	38	
23	31	32	31	43	38	35	38	37	39	40	
24	32	32	31	36	36	33	35	33	84	33	
25	42	31	31	43	38	32	32	36	65	41	
26	43	31	33	50	47	46	48	48	57	[illegible]	ZONE 3 WELL 26 – 32
27	32	31	56	51	54	50	52	54	71	109	
28	32	28	55	83	78	87	71	69	77	101	
29	35	27	65	88	76	76	82	119	154	148	
30	36	30	83	103	94	99	101	[illegible]	104	119	
31	35	31	38	128	117	105	109	105	114	122	
32	34	32	36	85	100	96	96	103	119	119	

52.