

DEWATERING INFLUENCE ON THE STABILITY OF THE FRESH AND SALT WATER INTERFACE IN  
FLANDERS (FRANCE)

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ABSTRACT

The encroachment of sea water into the coastal aquifer of the Maritim Flanders, with a surface of about 600 km<sup>2</sup>, is investigated in consideration of the interference of the agricultural dewatering on the position of the interface between fresh and salt groundwater near ground. Dewatering accentuates the groundwaters salinity which are transferred toward the channels then utilized for industrial water supply. Measures of hydraulic conductivity, of salinity and water levels have been realized on 258 piezometers distributed on 86 sites of observation during low and high water cycles during the 1979-1980 years. The simulations of interface fluctuations with a mathematical model by boundary element method with heterogeneous anisotropic soil allow optimization of the dewatering system which will used. Three simulated maps (at one, three and five days) indicate the geographical evolution of the zones polluted by salt water in the case of a systematic draining.

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INTRODUCTION

The agricultural practise in maritime Flanders polders appeals to the dewatering techniques because of the shallow depth of groundwater. The volume of groundwater so extracted is thrown into a multitude of canals and ditches. During rainy times the underground drains provoke the raising of the interface between fresh water and salt water. The great quantity of salt water disturbs the quality of superficial fresh water which is utilized for industrial water supply.

DESCRIPTION OF THE STUDY AREA (GEOLOGY, MORPHOLOGY)

Limited in the SW part by chalky outcrops of the Boulogne region and in the SE by argillaceous Flanders, the coastal plain of the North of France is about 10 to 20 kilometers wide and about 30 kilometers long.

The sedimentary deposits, constituted by argillaceous sands, sands and peats, have led to the clogging of the plain with the formation of offshore bars.

Pedologic study indicates a great variety of beds with sometimes five different deposits. The thickness of this heterogeneous anisotropic formation is thought to be about 30 meters, near the harbour of Dunkirk, where it overlies the "clay of Flanders".

The elevation of the plain is high (5 to 10 meters) along the coast with sand-hills and decreases gradually in the internal southern part (2 to -2 meters).

The groundwaters show an interface between the fresh water and the salt water which is related to the superficial water system and underground hydraulic moving in lateral connection with the sea (ref. 6).

#### FIELD RESULTS (AQUIFER PARAMETERS, WATER TABLE LEVELS, SALINITY)

A network of piezometers (258 on 86 sites) has been created and regularly from november 1979 to october 1980 some parameters were noted : hydraulic conductivity, piezometric values of water table, water salinity at 1.80 m, 2.80 m and 3.80 m underground (ref. 2).

Short injecting tests (Lefranc method) have been executed on all sites. The hydraulic conductivity (K) shows a particular statistical repartition. The transfer of these values realized on a gausso-logarithmic paper indicates the presence of two major distributions (ref. 2) :

- a first family from  $4.10^{-3}$  to  $2.10^{-1}$  m/d which reveals the argillaceous characteristic and the fineness of marine sediments (silt, clays),
- a second family from  $2.10^{-1}$  to 100 m/d relative at fine and coarse sands and peats.

In the area of Dunkirk, laboratory tests and pumping tests have shown (ref. 3), after Dagan and Hantush hypotheses, the anisotropy of the hydraulic conductivity ( $K_h/K_v$ ). The values are ranged between 2 (sands) and 15 (argillaceous sands) for the firsts tests and are equal to 10 for the seconds tests. Storing values fluctuate between 0.02 and 0.2.

The levels of the phreatic surface are regularly measured and some piezometric maps have been drawn. In the general case we note two great sectors (ref. 2) where the water levels are very low with negative values : between the St Omer channel and the Oye river (SE of Calais) and in the region of the Colme channel (S, SW and SE of Dunkirk).

The groundwater flows run from north to south along the coast inducing a marine intrusion of salty waters. In the inland the water is drained by ditches and canals during the rainy months.

The position of interface was obtained by electro-geophysical prospection (ref. 4) and permits a cartographical restitution of the thickness of fresh water.

The salinity values of groundwaters have been noted at the three respective depths of 1.80 m, 2.80 m and 3.80 m for a year on every piezometer.

The Spring season shows the contribution of rain with the appearance of fresh waters around Dunkirk.

We note the hydraulic passivity of the drains in november 1979 (before the winter recharge) which leads to some small perturbations in the south of Calais and in the sector of Colme channel.

In april 1980 these last ones increased after the winter activity of drains.

The statistical report of NaCl salinity values on a gausso-logarithmic paper (ref. 2) shows the presence of two families of concentration on both sides of the 1 g/l limit :

- from 1 to 10 g/l, the first one characterizes the drain activity in 35 % (november 79) and in 55 % (april 80) of the regional cases,
- from 0.5 to 1 g/l the second one is peculiar to the undrained region. We can see the importance of the drainage activity on the rise of the interface. It varies differently wether there is or not a draining in some parts of Flanders. Theoretically the absence of drains leads to a decreasing of the NaCl concentrations when the layer of fresh water increases after rains (the water table is near ground surface).

In other words when drains are present and active the concentration increases with the time (the rate of infiltration is constant). A third case can be considered : the drain is passive during low water and active in high water.

#### MATHEMATICAL MODEL

The complexity of the mobility of the interface requires a mathematical tool which gives a good insight into the effects of any modification of parameters (hydraulic conductivity, anisotropy and its directions, boundaries conditions, densities, drain discharges...).

A idea of it is obtained by making the parameters vary in given problem. The flow can be assumed to be two-dimensional in usually cases and an analytical function method was established by Van Der Veer (ref. 5) who illustrated this method by a computer program for two-dimensional groundwater flow with steady and non steady flow patterns in arbitrary shaped regions that may contain several fluids and inhomogeneities.

Many cases taken in the study area have been computed with different hypotheses. In a first step we have examined an homogeneous soil and in a second step a multi-bed soil (ref. 2).

The essential and practical conclusions are the following ones :

- the rise of the interface is very important when the values of the coefficient of permeability are increasing from the lower to the upper part of soil section,
- the existence of an argillaceous bed contributes to an attenuation of the interface movement,

- the quarter of the Flanders area is probably submitted at a strong contamination by saline water as soon as the activity of drains begin,
- 45 per cent of the Flanders area are partially polluted depending on the permeability values.

DYNAMIC OF POLLUTION CAUSED BY SALINITY

We have just seen the importance of the permeability values distribution with respect to the interface mobility when the theoretical stability of the piezometric level remains so during along enough period of time (one week). This work hypothesis must be completed by the examination of the impact of a rough recharge of the water table during a short period which however acts upon on the interface position.

We have reported on figure 1 two modalities of an apprehension of the dynamic of the saltness phenomenon.

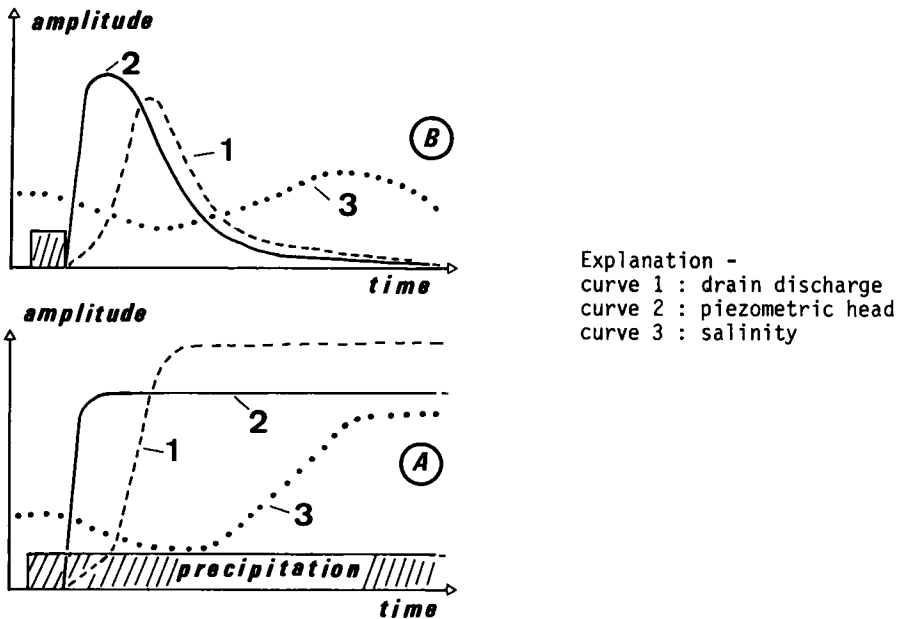


Fig. 1. Modalities of the interface mobility in permanent state (A) and after a rough recharge of short period (B).

Modality "A". A constant precipitation make a water level steady owing to the drain activity. We note a certain inertia of the draining system observed experimentally on the field (ref. 1). The curve of salinity variation (stable at  $t = 0$ ) at the output of the draining system decreases at first time because of a vertical accretion of fresh water which compensates the head of salt water and which generates a start of the hydraulic activity of the drains. As soon as the drain discharge

reaches a critical value the interface stabilizes momentarily and begin rising (with an increasing of salinity). The mathematical simulation very well shows this process which keeps a fixed value when the interface meets the top of the water table.

Modality "B". A rough precipitation during a short period generates a rise of the water table level which quickly enters in its drying up phase. After a delay the activity of draining appears during a short time without reaching the maximum intensity. A little rise of the interface occurs with a slow stabilization then it decreases until it reaches a steady state (precipitations are absent during the considered period).

Simulation maps of salinity. The application of the mathematical method for the setting of simulated draining on the whole Flanders area has been tried in order to show up the sensitive sectors with regard to a contamination by salt water. We have supposed a state of active and constant draining (with respect to hydraulic parameters of every site) during three periods of one, three and five days. We have retained the sites which will show an intersection of the drain position with the interface at 36 g/l of salt. The three maps (figure 2) indicate the geographical

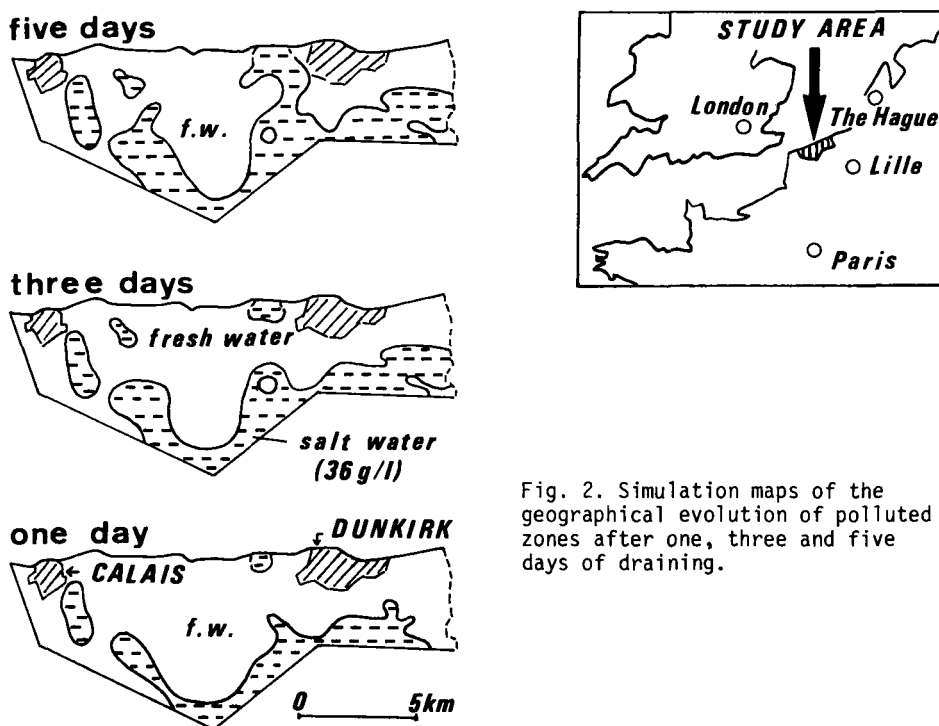


Fig. 2. Simulation maps of the geographical evolution of polluted zones after one, three and five days of draining.

evolution of polluted zones by salt water in the case of a systematic draining (inter-drain space of 12 m, drain diameter : 0.06 m and head of water table on the drain : 0.60 m). We notice a general displacement during time of the salt water boundary from S to N of Flanders with a junction sector with the coast at the W of Dunkirk. One then two little lenticular districts appear S-SE part of Calais. Practically these maps permit a delimitation of sore regions as regards pollution where appropriate modalities either drainage or of throwing out salt waters into specific canals (in connection with sea) will be proposed.

#### CONCLUSIONS

The study of the interface mobility in the coastal aquifer of Flanders has required the setting of a vast program of realization and supervision with several hundred short piezometers. After a first period of physical and hydraulic parameters acquisition, a mathematical modelisation, by the boundary elements technics and by the analytical function method, has allowed us to know the influence of de-watering on the interface rising with regard to hydraulic parameters variations in connection with the geological and pedological contexts.

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#### REFERENCES

- 1 H. Fourrier, Etude de la salinité des eaux de drainage dans les waterings du Nord et du Pas-de-Calais. D. E. A. Université Lille I, (1979), 43 p., 7 tabl., 17 fig., 6 ann.
- 2 J. Mania et V. Meens, Etude de l'interface eau douce - eau salée de la nappe côtière des waterings du Nord et du Pas-de-Calais (Flandre maritime). Incidence du drainage. Rapport SRAE n/80, (1980), p. 60.
- 3 S. Ramon, Etude de la protection des eaux naturelles contre les pollutions en hydrocarbures. Rapport BRGM 72SGN255NPA, (1972), 21 p., 3 ann.
- 4 Sogreah, Etude des ressources en eau des waterings, salinité des eaux de surface. Rapport 10400 A, (1970), 41 p., 5 pl.
- 5 P. Van Der Veer, Calculation methods for two dimensional groundwater flow. Rijkswaterstaat communications, n° 28, (1978), 172 p., 68 fig.
- 6 Voies Navigables du Nord - Pas-de-Calais, Etude hydrogéologique des waterings. SOGREAH R. 10284, BURGEAP R. 480 et BRGM 695GL290NPA, (1969), 64 p., 8 pl.