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A NEW HYDROGEOLOGICAL MAP OF GUELDERLAND AND FLEVOLAND[1]

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ABSTRACT

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A new mapping technique is proposed to represent on one sheet the hydrogeological data of a region. The main features represented are:
– The structure of the alternation of aquifers and resisting layers.
The map gives the transmissivity of aquifers and the ranges in hydraulic resistance of less pervious layers. The symbols used are coloured beams (thickness indicating transmissivity values and colour the geological origin).
– Ground-water heads in the form of contour lines and the relevant surface water pattern.
– The location and the extent of ground-water extraction, indicated by circles or squares of a variable size.
– Ground-water quality by means of the distribution of fresh and brackish ground-water.

The map has been composed for the situation of The Netherlands, but can most likely be used for any area, where the aquifer systems consist of unconsolidated sediment. Another requirement is that the available data allow a quantitative representation.

PURPOSE AND GENERAL OUTLINE

The usual ways to represent hydrogeological features on a map are not very satisfactory with regard to the situation in The Netherlands. The main reason is evident: the essentially three-dimensional characteristics of occurrence and flow of ground-water have to be represented on two-dimensional maps. Another reason is that the emphasis in The Netherlands tradionally lies on a quantitative description of ground-water flow; many engineers took part in the development of geohydrology to solve drainage problems connected with engineering constructions. In many other countries where a more complicated geological structure determines the hydrogeological conditions, the study of ground-water phenomena belongs to the domain of the geologist and is of a more qualitative nature. Hence, mapping of hydrogeological information is often regarded as a special subject of a general geological mapping exercise. This approach, however, does not comply with the situation in The Netherlands, where much quantitative information is available and therefore also expected to be included in a hydrogeological map. In the past, two methods have been applied to overcome the above two difficulties.

JELGERSMA & VISSER (1972) drew a horizontal projection of many variables on only two maps. As they used a small scale (1:1,500,000), they had to omit many details; nevertheless their maps give an overloaded impression. This would have been more serious, if they had included values of permeability, transmissivity and the extent of ground-water abstractions.

The GROUND-WATER SURVEY TNO uses another method to compose ground-water maps of The Netherlands. The maps already published, on the scale 1:50,000, consist of a relatively large number of separate sheets in black and white. Each sheet represents different properties of the ground-water in the area concerned. A complete picture of the ground-water situation is only gained by consultation of all the maps, together with a written document. In this way any desired detail can be represented without overloading the map. Nevertheless, the user will find difficulties in obtaining a general view of the hydrogeological conditions of the area.

Given this situation, the Study Committee on Water Management of the Provincial Water Board of Guelderland asked for the composition of a hydrogeological map of the province of Guelderland. The challenge was to provide on one sheet a general view of the ground-water conditions, representing the available information also in its quantitative aspects, but without loosing readability. The result has been added as an appendix to this issue of Geologie en Mijnbouw.

The target group of users of the map comprises:
– Government agencies dealing with management aspects of ground-water quantity and quality;
– Private firms or individuals interested in ground-water as a resource, or as part of the environment;
– Geohydrologists, starting an investigation to solve a particular problem.

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Primarily, the map shows four features pertinent to ground-water:
1. The geohydrological structure, appearing from the alternation of aquifers and resisting layers. The map gives an indication of the transmissivity values of the aquifers and ranges in the hydraulic resistance of the less pervious layers.
2. Ground-water heads represented by contour lines and the relevant surface water pattern. The reference level for ground-water heads is the Netherlands datum plane, which is about mean sea level.
3. The location and the extent of ground-water abstractions.
4. Ground-water quality by means of the distribution of fresh and brackish ground-water.

Additionally, some particular geological features relevant to the ground-water situation have been marked. For the mapped area the occurrence of ice-pushed ridges and the presence of shallow fault systems are important.

SET-UP AND SYMBOLS

Generally, the hydrogeological conditions in The Netherlands make mapping difficult, because a complex vertical variability does not allow straightforward projection on a map. The Netherlands have a mainly Quaternary aquifer system, composed of successive sub-aquifers separated by relatively pervious resisting layers. Most hydrological processes (e.g. withdrawals) affect the whole system up to the surface. At the surface, ground-water has many links with a sometimes dense drainage system. Moreover, the ground-water tables are mostly at shallow depth, also implying a close relation between ground-water and moisture in the unsaturated zone, and hence, with vegetation in natural and agricultural areas. Pollution from above can easily penetrate into deeper layers, depending on the stratification of the aquifer system.

For reasons mentioned, the geohydrological structure has to be represented in some detail. On the accompanying map (enclosure) the vertical stratification could be shown in sufficient detail by using differentiated horizontal beams. The thickness of the coloured bars represents the transmissivity value of the sub-aquifer concerned. This way of representation implies that the accuracy of representation is about one unit, i.e. 1 mm corresponding with 100 m^2/day.

With different colours the various geological formations of the sediments of the aquifers are distinguished. They mark lithological differences which can easily be recognised in the field and possess characteristic geohydrologic features, such as permeability. The black lines indicating (semi-)confining layers, only give the ranges in the hydraulic resistance. The reason is that the available observations do not allow a more detailed representation.

The ground-water contour lines represent the head in the deepest aquifer where sufficient observations are available to make mapping possible. In this way the regional ground-water flow pattern, less disturbed by local peculiarities, shows up clearly. Although differences in head exist for other subaquifers, the general flow pattern in those layers will be similar, due to interrelation.

Ground-water withdrawals have been divided into well fields for public water supply and other (mostly industrial) abstractions per municipality. Public water supply withdraws ground-water from well-defined well fields of large capacity, whereas other withdrawals are mostly smaller and more dispersed. In both cases, however, the amount of ground-water abstracted in 1977 can easily be calculated by multiplying the surface of the enclosed area by a water layer of 300 mm. A value of 300 mm/year represents the long year mean of rainfall excess (precipitation minus evapotranspiration) over the mapped area. Hence, the circles or rectangles on the map represent an area for which the full ground-water recharge is equivalent to the volume of ground-water abstracted. The area affected by the withdrawal of course will usually be larger than the circles or rectangles.

The lower limit for a ground-water abstraction to be represented on the map is 300,000 m^3/year. Hence, many small abstractions, e.g. supplying sprinklerwater for agriculture, are not indicated. The effect of each individual small abstraction will be small: as a whole they may, nevertheless, influence ground-water conditions. Notably in recent years the use of sprinklers has increased; yet it is assumed that the present effect is still small. Anyhow, the available data on locations and capacities are scarce.

The mapping of the surface water pattern has been accomplished as follows: In areas where the ground-water is drained by freely discharging brooks and rivers, only the largers streams have been marked. Most man-made canals have not been marked. In many cases their beds contain silt layers with a large resistance to the flow of ground-water; hence, the relation between canal water and ground-water is practically negligible. The western and southwestern parts of the area consist of polders, where excess water is discharged mechanically. The polders generally contain a dense drainage pattern of ditches, in which a fixed polder level is maintained. Ground-water heads and polder levels are mostly strongly related. Nevertheless, only the larger collecting ditches have been marked on the map.

Only one aspect of ground-water quality has received special attention, namely salinity. The presence of brackish ground-water (chloride content larger than 500 mg Cl^-/l) is represented in the coloured bars. When the aquifer concerned partly contains brackish ground-water, the brackish water symbol only fills the relevant part of the bar.

Two geological features have also been represented on the map. The first is the occurrence of ice-pushed layers underground. Land-ice glaciers in the Saale Glaciation reworked former deposits, whereby valleys and ridges were formed. Subsequently, finer material, partly derived from the ridges, again filled the valleys, thus creating confining layers of sometimes high resistance. In the ridges the layers locally have an inclined position, leading to irregular and unexpected patterns in horizontal and vertical permeability.

Shallow fault systems in the western part of the area influence hydrogeological conditions insofar that sudden changes in thickness of aquifers and hence, transmissivity may occur. Other fault systems, not having serious consequences for hydrology, have been omitted.

The symbols used on the map correspond, where possible, with symbols and colours recommended by UNESCO (1970).

The set-up of the map enables the user to adapt it for other purposes or for other areas. Examples are:

- Other types of withdrawal can be represented by comparable symbols, such as triangles of different size for agricultural abstractions.
- Quality aspects can be emphasized by representing more components, e.g. in figures or diagrams. Sources of pollution, such as sanitary landfills, may additionally be represented on the map.
- For other areas, different geological features may replace the ones chosen for this map.

FEATURES NOT REPRESENTED

The map does not show every detail of the hydrogeological conditions; choices have been made and therefore other possibilities were excluded:

- Basic data like drilling logs, ground-water head observations and pumping test results are not given. The map already contains the interpretation of such data. Hence, the reader cannot simply evaluate the reliability of the data presented.
- Geometrical and geohydrological properties of aquifers and confining layers are represented by transmissivity and hydraulic resistance respectively. Hence, one cannot directly read other properties from the map such as depth, thickness and horizontal and vertical permeability.
- The relation between ground-water and many other parts of the hydrological cycle such as the soil moisture in the unsaturated zone is not represented. Only the link between ground-water and surface water is partly indicated.
- Again, quality variations within the fresh ground-water are not given, although many data exist for the mapped area. The main difficulties in representing ground-water quality are, firstly, that it is determined by many not uniformly varying parameters and, furthermore, that ground-water quality should be defined in relation to the purpose for which the ground-water is considered.

HOW TO READ THE MAP

The possible use of the map will be illustrated by two examples.

I. Imagine a geohydrologist, who has to investigate the dewatering of a building pit at the conjunction of Apeldoorns Kanaal and the river IJssel in Dieren some 10 km north-east of Arnhem. Underneath the building pit the ground-water table has to be lowered to a depth of mean sea level (MSL).

From the map he may conclude that the underground hydrogeological structure is as follows:

- The first layer below landsurface is a confining layer with a hydraulic resistance of more than 500 days. This layer is only present in a narrow zone along the river IJssel; it may be assumed that the layer consists of Holocene river deposits.
- The second layer is an aquifer, formed by Upper Pleistocene sediments and having a transmissivity of about 1000 m^2/day.
- The third layer below surface is again a less pervious layer with a hydraulic resistance of more than 500 days; the influence of this layer diminishes rapidly in a westerly direction.
- The deepest layer of interest to the hydrogeological situation is an aquifer filled with Lower Pleistocene and older deposits and having a transmissivity of about 2000 m^2/day.

Furthermore, the geohydrologist may read from the map that the ground-water head at Dieren is about MSL + 8 m. Hence, drawdowns at the building pit have to be about 8 m. Other hydrological factors of importance in this case are the presence of the river IJssel, having a connection with ground-water and a ground-water withdrawal of about 4 million m^3/year at a nearby well field situated in the shallow unconfined aquifer.

With these data, derived from the map, the geohydrologist can make a rough calculation, resulting in an estimate of the total yield of the dewatering wells and the ground-water drawdowns in the vicinity.

Further (field) investigations should be carried out with regard to the extent and the values of hydraulic resistance of both resisting layers.

II. The second example concerns a regional planner who wants to get an insight in present withdrawals of ground-water and in future use of ground-water resources. For that purpose, he has to sub-divide the area into a number of regions.

The Veluwe

The Veluwe is the central part of the area mapped where a number of ice-pushed ridges is present, which form relatively high hills. Due to the elevated position and the high permeability near to the surface, the Veluwe is a recharge area, where nearly all rainfall excess infiltrates into the soil. Ground-water flows to the surrounding valleys on all sides.

The present withdrawal of ground-water mainly takes place in a transition zone between the hills and the valleys. At the southern margin of the Veluwe large pumping capacities have been installed, so that the ground-water recharge of large areas is pumped and no further extension will be possible.

In the northern and central part of the Veluwe some additional ground-water withdrawal still might be possible.

The transmissivity is large. The near absence of resisting layers implies that special attention should be given to the protection against pollution from land surface.

The Guelders Valley
The Guelders Valley is situated in between two ice-pushed ridges, the Veluwe in the east and the Utrecht Hills in the west. Ground-water from the ridges recharges the deep ground-water under the valley which, in turn, is discharged by upward seepage. Shallow ground-water, also fed by local rainfall excess, is drained by a number of brooks and rivulets.

Present ground-water abstractions show a small capacity, especially in the northern part of the Guelders Valley. Some extension will be possible, which, however, will be restricted by the consequences of hydrological effects in the shallow aquifer. Another restriction is formed by the presence of a ridge of brackish ground-water underneath the thalweg of the ground-water contours. Withdrawal of ground-water from the main aquifer can be expected to be well protected against pollution by a resisting layer.

Flevoland
The newly reclaimed polders in the North-West of the mapped area, which form Flevoland, also receive ground-water from the Veluwe hills. Differences from the Guelders Valley are:

- The shallow subsoil consists of a resisting layer.
- Large areas underground are occupied by brackish ground-water.

In 1977 only one well field for public water supply existed in the polders. Future extensions will be possible. Restrictive factors to ground-water development are the presence of brackish ground-water and possible consequences of hydrological effects in the areas adjacent to Flevoland. Favourable factors are the large transmissivity of the main aquifer and the presence of protective layers.

The IJssel Valley
The valley of the northern Rhine-branch, the river IJssel, is hydrogeologically characterized by the underground presence of clay layers of very high hydraulic resistance. The lower aquifer is nearly fully confined. The ground-water in the deep aquifer is recharged by ground-water originating from the west (the Veluwe) and from the east, it is mainly discharged by pumping. Most existing wells are situated in the deep aquifer. Restrictions to withdrawal are upconing of deep brackish ground-water and hydrological effects in the recharge areas at large distances. Possibilities for extension will be small, but not absent.

East Guelderland
The area East of the IJssel Valley is hydrogeologically rather homogeneous. It has one, mostly unconfined, aquifer. In a zone near the German border the aquifer becomes so thin that it practically vanishes, except for a few subsurface gulley structures filled with sand.

A large number of well fields for public and industrial water supply have been installed, most of which have a relatively small capacity. An extension of withdrawal has to be restricted, due to consequences of hydrological effects at land surface. Special attention has to be given to pollution from land surface.

The Rhine Valley
The south-western part of the area mapped is occupied by a broad valley, in which two major branches of the river Rhine and the river Meuse flow towards the North Sea. An alternation of fluviatile clay and sand-layers occurrs underground. The aquifers are largely recharged by the rivers at a high level and partly drained at low levels. Nevertheless, some recharge also comes from nearby elevated recharge areas like the Veluwe.

In the eastern part of the area the town of Nijmegen and surroundings are situated on ice-pushed ridges, comparable to the Veluwe hills.

In the area around Nijmegen heavy pumping occurs but elsewhere there is a relatively large potential for extension of ground-water abstractions. In some areas the presence of brackish ground-water is a restrictive factor. Well fields should generally be protected against pollution from land surface.

From these remarks the regional planner of this example will have a sound base for further discussion although he cannot derive at which places and to what amount an extension of the present ground-water abstractions is possible.

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