

REVIEW OF GEOHYDROLOGICAL ACTIVITIES IN THE NETHERLANDS SINCE WORLD WAR II, IN PARTICULAR OF THE GOVERNMENT INSTITUTE FOR WATER SUPPLY

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ABSTRACT

Geohydrological activities in The Netherlands have undergone some remarkable developments since World War II. Besides the Government Institute for Water Supply many other agencies and institutes have contributed to this progress. Scientific achievements in geohydrology have largely run parallel with the rapid social and economic development of the Netherlands since the war.

I. INTRODUCTION

Hydrology has shown a remarkable development since World War II. The application of the achievements in physics and chemistry and the use of models and computers to solve mathematical problems have greatly promoted this development. Basic to this development, however, were the problems of water-economy in both developing and highly industrialized countries. The main objects of investigation have been the exploration and exploitation of water resources on the one hand and the protection against floods on the other hand. The water pollution problem of densely populated areas, resulting from modern economic development, is a great stimulus to water management and thus to the hydrological sciences.

UNESCO has made great efforts to promote international co-operation in the field of hydrological sciences. A considerable number of international

organizations, amongst them the International Association of Scientific Hydrology (IASH), the International Council of Scientific Unions (ICSU), the Food and Agricultural Organization (FAO), the World Health Organization (WHO), the World Meteorological Organization (WMO) and the International Atomic Energy Agency (IAEA) contributed to the most important hydrological research project which has ever been undertaken, viz. the International Hydrological Decade (IHD) which runs from 1965 to 1974. Its main objectives are the training of hydrologists, the development of hydrological sciences and the establishment of an international net work of hydrological stations. The recent history of hydrology in the Netherlands should be considered in this context.

To the Dutch people water has always been both a friend and an enemy. Frequent floods – during the has great flood of 1 February 1953, 1835 people lost their lives – brought the construction of dikes and the floodprotection in general to greater perfection. The positive side of the abundance of water in the Low Countries was the navigability of the many watercourses. Since the 18th century it was the task of the “Waterstaat” (State Public Works) to look after the flood protection, the management of the major rivers and the construction of large canals. Christiaan Brunings (1736-1805) is usually considered as the father of the “Waterstaat”. It has been founded as a governmental institution besides the local “Waterschappen” (Water Boards) which existed since the Middle Ages.

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In modern times other problems became important like water management for agricultural purposes and public water supply. To tackle these problems several governmental services, scientific institutes and consulting agencies were created in addition to the old "Waterstaat". The "Rijks waterstaat" (State Public Works, RWS), the Land Drainage and Land Improvement Department (Cultuurtechnische Dienst, CD), the State Geological Survey (Rijksgeologische Dienst, RGD) and the Government Institute for Water Supply (Rijksinstituut voor Drinkwatervoorziening, RID) may be mentioned among the governmental agencies. Apart from universities, viz. the Technological University and the Agricultural University, the Institute for Land and Water Management Research (Instituut voor Cultuurtechniek en Waterhuishouding, ICW), the Soil Survey (Stichting voor Bodemkartering Stiboka) and the Ground Water Survey (Dienst Grondwaterverkenning, DGV-TNO) are engaged in hydrology. Local public services such as provincial agencies and water boards, water works, landimprovement companies and engineering consultants carry out hydrological studies.

It is clear that where so many different organizations are active, the need for co-operation was felt. In 1946 the Committee for Hydrological Research TNO was founded, in which all the services and institutes dealing with hydrology are represented. This committee has greatly promoted the development of hydrological research. The committee established working groups on lysimeter research, rainfall data and geoelectrical research, and assisted in the foundation, first of the Archives for Ground Water Levels and later of the Ground Water Survey TNO (Commissie voor Hydrologisch Onderzoek TNO. Proceedings 1952- present). Only recently an agreement was reached between the RID, RGD, DGV, RWS and ICW in the field of geohydrology to integrate their regional geohydrological working programs. Informal contacts between geohydrologists are organized by the "Hydrologisch Colloquium", a working group.

Within the scope of this article it is not possible to discuss all the activities of the above mentioned services, institutions and agencies. Moreover only is dealt with groundwater hydrology. The activities of the Government Institute for Water Supply (RID), which carried out a great number of geohydrological studies, in particular will be treated.

II. THE GOVERNMENT INSTITUTE FOR WATER SUPPLY

The local Water Boards and the "Waterstaat" when dealing with the problem of the excess water in the polders (areas below sealevel), were mainly concerned with pumpage of surface water. This technique did not require geohydrological studies. However, this water excess is due to seepage of ground water and therefore it is a geohydrological problem. Only in the present century the drainage of construction sites by means of pumped wells stimulated the development of geohydrology.

The main stimulus for the development of geohydrology was given by the exploration and exploitation of groundwater resources for public water supply. The engineers of the oldest Dutch Water works – those of Amsterdam, founded 1853 – have played a major part in this development. The progress of bacteriology stressed the importance of groundwater for public water supply. A piped water supply with bacteriologically reliable water appeared to be of vital importance to avoid epidemics. Therefore a State committee for Water Supply was established in 1910 in order to advise the government with respect to the promotion of public water supply (Gedenkboek 1938). The RID and the CCVD (Central Committee for Drinking Water Supply) evolved out of this State Committee in 1913. In particular the RID, under the inspiring management of its directors, among whom especially Prof. W.F.J.M. Krul should be mentioned, has given geohydrology an equivalent place to surface water hydrology.

As ground water exploitation generally causes a lowering of the ground water table and as lowering of the ground water table in the Netherlands may cause damage to agriculture, studies with respect to ground water exploitation are often carried out in co-operation with agronomists.

Permission for ground water recovery for public water supply and for industrial purposes is given under two legal statutes, the "Grondwaterwet Waterleiding bedrijven" and the "Hinderwet" respectively. The COGROWA (Committee "Grondwaterwet Waterleidingbedrijven") and the COWABO (Committee Ground Water Recovery) are the official technical advising agencies to the Minister for the implementation of these laws.

III. THE DEVELOPMENT OF GEOHYDROLOGY IN RELATION TO SOCIAL AND ECONOMIC DEVELOPMENT

Within the scope of this article it is not possible to deal with all the particulars of the recent history of geohydrology. As to the history of geohydrological research before 1946 reference is made to the excellent reviews of Prof. Krul (K r u l, 1946, 1962).

The social-economical rebuilding ("Wederopbouw") after World War II, led to the resumption of the construction of large public works, the geohydrological aspects of which have been studied by the RID (Velsen Tunnel, Zuiderzee reclamation works). The Marshall Aid furnished the funds for an extensive research program for agricultural water management, the COLN research program (V i s s e r, 1958). The growing economy and the increasing population in the fifties stimulated the demand for water for public and industrial needs, and also resulted in the construction of an increasing number of public works (roads, tunnels, canals, harbours). The following table illustrates this growth.

Growth of population, the gross national product and the water production by the waterworks in the Netherlands.

	1950	1960	1970
Population January 1	10,0.10 ⁶	11,4.10 ⁶	13,0.10 ⁶
GNP market prices	f 19.90 ⁹	f 43.10 ⁹	f 113.10 ⁹
Production water works	319.10 ⁶ m ³	504.10 ⁶ m ³	872.10 ⁶ m ³

A great impulse to hydrological research was given by the flood disaster of 1 February 1953, causing a damage of approximately one billion guilders apart from a considerable loss of human lives. The disaster led to the Delta Act of 1958 regulating the closure of the sea arms in the provinces of Zuid-Holland and Zeeland with the exception of the Westerschelde and of the Nieuwe Waterweg. The works started soon after the flood in 1954 (Rapport Deltacommissie 1961).

Nowadays the planning of the future water supply of the country is becoming of predominant importance. Among the studies concerning the water management and the water supply for the year 2000

the report of the CCVD regarding the Future Drinking Water Supply (1965), the "Nota Waterhuishouding" (Report on water management) of the RWS (1968) and the "Nota Basisplannen Toekomstige Drink- en Industrierwatervoorziening" (Masterplan of the future public and industrial water supply; in press) of the RID should be mentioned. The studies in the latter report are based on an estimate of 17,9 million inhabitants in the year 2000. The report results in a prognosis of the water demand of population and industry of 4,5 to 5,5 billion m³ per year in 2000. The exploitable groundwater resources however are estimated at 1.9 billion m³ per year, which implies that the greater part of the water supply will have to be drawn from surface water resources.

It is quite evident that after the year 2000 geohydrological studies will still be necessary. Apart from geohydrological investigations for the construction of public works among which storage basins for surface water, many other investigations will have to be carried out in relation to efficient management of the country's water resources. In this connection the protection of the groundwater resources against pollution on the one hand and a reasonable distribution of the limited amounts of exploitable ground water among the various groups of users on the other hand (public water supply, agriculture, recreation, conservation of nature) should be mentioned.

IV. SCIENTIFIC DEVELOPMENTS IN GEOHYDROLOGY IN THE NETHERLANDS

Some developments concerning mathematics, model techniques, field investigations and techniques of measurement will now be treated.

Mathematics and model techniques

The groundwater flow can be described by D a r c y's Law (1856): $v = -ki$, v stands for filtration velocity, i for the hydraulic gradient and k for the permeability coefficient. This law is analogous to laws governing other flow phenomena, as for example Ohm's Law for electricity, Poiseuille's Law for laminar fluid flow and Fourier's Law for heat flow. The mathematical treatment of all these flow phenomena takes place with the help of the potential

theory. Geohydrologists have frequently consulted solutions provided by other sciences using the potential theory.

Before World War II especially permanent ground water flow was studied. The names of De Glee (1930), Mazure (1936), Steggewentz and Van Nes (1939) should be mentioned in this context.

In the U.S.A. Theis (1935) and Jacob (1940) already applied formulae for nonpermanent fluid flow. Independently, other problems concerning nonpermanent groundwater flow were solved in the Netherlands by Steggewentz (1933) and Edelman (1947). Formulae concerning nonpermanent flow in agro-hydrology have been developed by KraeyenhoffvandeLeur (1958), Wesseling (1959) and Ernst (1962).

All the above mentioned formulae are applicable to one aquifer and a homogeneous fluid only. In the Netherlands problems concerning flow through multi-layered aquifers and multiple fluid flow were successfully teckled by Huismann and Kemperman (1951), De Josselinde Jong (1960) and Brugeman (1969).

For the growth of the crops it is essential that research into the hydrology of the zone of aeration and into the salt content of groundwater should be

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done. Formulae concerning groundwater flow in the capillary fringe were developed by Wesseling (1960, 1969) while salinisation problems were treated by Ernst (1969).

The analogy of flow phenomena made it possible to solve hydrological problems by the aid of analog model techniques, for example with the Hele-Shaw model or with the resistance capacity network analog. The RID has played a major part in developing these models (Dietz, 1944; Santing, 1963). Nowadays they are in use at the RWS, the ICW, the land improvement companies and other institutions.

Besides analogs, digital computers are employed for the solution of geohydrological problems. Edelman (1947) and Van Deemter (1950) used numerical methods to solve groundwater flow problems. Some of these methods have been adapted for digital computation (Verruyt, 1970).

Field investigation and measurement techniques

The studies made in the interest of hydraulic works, water supply and drainage works are mostly preceded by field investigations, whereby the determination of the permeability and other geotechnical constants is important.

Besides data concerning ground water heads and the chemistry of the ground water, knowledge of the structure of the subsoil is fundamental. Classical methods in use are borings, ground water sampling for chemical analysis, registration of piezometers and pumping tests (Kruseman and De Ridder, 1970).

The problems involved in drainages and irrigation which were studied before World War II by the "Landbouwproefstation en Bodemkundig Instituut" (Institute of Soil Science) led to field investigations too (Hooghoudt, 1940, 1943). The imperfect knowledge of the permeability of the soil and the subsoil formed one of the main problems for the application of drainage formulae. For this reason Hooghoudt propagated geohydrological mapping of the Netherlands. Afterwards De Ridder and others realized this mapping for some regions (Agrohydrologische profielen 1957, De Ridder, Hondius, Hellings, 1967; Ernst, De Ridder, De Vries, 1970).

The Institute of Soil Science also effectuated research into the infiltration and percolation of the precipitation, amongst others by method of lysimeters. The working group on lysimeters TNO has continued this research.

In paragraph III the COLN research for agricultural water management was already mentioned (Visser, 1958).

To serve the public water supply several regional studies were carried out in the course of the years, as for example in the Veluwe, in the province of Limburg and in the Northeast of the Netherlands (Van Dissel, 1933; Jongmans, 1941; Pattijn, 1966; Gischler, 1967). In recent times for the Masterplan of the water supply much work is carried out (Basisplannen – toekomstige drink- en industriewatervoorziening, in press).

The Groundwater Survey TNO is engaged in a systematic geohydrologic mapping program with the purpose of providing basic data for the management of the water resources (Lekahena en Smoor, 1970).

In the Netherlands attention was also paid to modern research techniques, like geophysical research; remote sensing and the use of isotopes in hydrology (Dijkstra and Volker, 1957; Van Dam, 1964; Vogel, 1967; Mook, 1968).

Hydrochemical research was recently carried out by Geirnaert (1971).

REFERENCES

- Agrohydrologische profielen van Zeeland (1957) – Den Haag.
- Bruggeman, G.A. (1969) – The reciprocity principle in flow through heterogeneous porous media Symp. on the fundamentals of transport phenomena in porous media, I.A.H.R. Haifa.
- Bijdragen tot de geologie en hydrologie van het Deltagebied Geologie en Mijnbouw (1960).
- Commissie voor Hydrologisch Onderzoek TNO (1952) – present. Verslagen en Mededelingen.
- Dam, J.C. van (1964) – A simple method for the calculation of standard-graphs to be used in geo-electrical prospecting, thesis Delft.
- Deemter, J.J. van (1950) – Theoretische en numerieke behandeling van ontwaterings en infiltratie stromingsproblemen, thesis Wageningen
- Dietz, D.N. (1944) – Ervaringen met modelonderzoek in de hydrologie, Water, 3.
- Dissel, E.D. van (1933) – Wateronttrekking aan de Veluwe, Den Haag.
- Dijkstra, J. en A. Volker. (1957) – Geo-electrisch onderzoek op het IJsselmeer, Rapporten en mededelingen Z.Z.W. nr. 6.
- Edelman, J.H. (1947) – Over de berekening van grondwaterstromingen, thesis Delft.
- Ernst, L.F. (1962) – Grondwaterstromingen in de verzadigde zone en hun berekening bij aanwezigheid van horizontale evenwijdige open leidingen, thesis Utrecht.
- Ernst, L.F. (1969) – Ground water flow in the Netherlands Delta area and its influence on the salt balance of the future Lake Zeeland. ICW Techn. Bulletin nr. 64.
- Ernst, L.F.; N.A. de Ridder en J.J. de Vries (1970) – A geohydrological study of East Gelderland, Geologie en Mijnbouw.
- Gedenboek Drinkwatervoorziening in Nederland 1913-1938 (1938) – Den Haag.
- Geirnaert, W. (1971) – The occurrence of cation exchange in groundwater, H₂O nr. 6.
- Gischler, C.E. (1967) – A semi qualitative study of the hydrogeology of the North Netherlands, Verh. KNGMG, Geol. Serie dl 24.
- Glee, J.G. de (1930) – Over grondwaterstromingen bij wateronttrekking door middel van putten, thesis Delft.
- Hooghoudt, S.B. – Bijdrage tot de kennis van enige natuurkundige grootheden van de grond, nr. 7 (1940), nr. 8 (1943) Rijksuitgeverij
- Huisman, L. en J. Kemperman (1951) – Bemaling van spanningsgrondwater, De Ingenieur nr. 13.
- Jongmans, J.W., W.F.J.M. Krul en J.J.H. Vos (1941) – Waterwinning in Zuid-Limburg, Maastricht.
- Josselin de Jong, G. de (1960) – Singularity distributions for the analysis of multiple-fluid flow through porous media, J. Geoph. Res. II.
- Krayenhoff van de Leur, D.A. (1958) – A study of nonsteady ground water flow, De Ingenieur 70.
- Krul, W.F.J.M. en F.A. Lieftrinck (1946) – Recent ground water investigations in the Netherlands, Amsterdam. 1946.
- Krul, W.F.J.M. (1962) – Development of geohydrological knowledge and research in the Netherlands, Geol. en Mijnbouw.
- Kruseman, G.P. en N.A. de Ridder (1970) – Analysis and evaluation of pumping test data, ICW Bulletin II.
- Lekahena, E.G. en P.B. Smoor (1970) – Toelichting bij de kaartbladen 49 Oost Bergen op Zoom en 50 West Breda. Grondwaterkaart van Nederland DGV-TNG, Delft.
- Luchtwaarneming met niet-conventionele systemen (1970) – De Ingenieur 33.
- Mazure, J.P. (1936) – Geohydrologische gesteldheid van de Wieringermeer, Rapporten en Mededelingen Z.Z.W. nr. 5.
- Mook, W.G. (1968) – Geochemistry of the stable carbon and oxygen isotopes of natural waters in the Netherlands, thesis Groningen.
- Patijn, R.J.H. (1966) – Waterwinning in Zuid en Midden Limburg, Med. Geol. Stichting.
- Rapport Deltacommissie (1961).
- Ridder, N.A. de; P. Hondius en A.J. Hellings (1967) – Hydrogeological investigations of the Peel region. ICW Techn. Bulletin 48.
- Santing, G. (1963) – Modelonderzoek. Cie voor Hydr. Ond. TNO, Versl. en Med. 6.
- Steggewentz, J.H. (1933) – De invloed van de getijbeweging van zeeën en getijrivieren op de stijghoogte van grondwater, thesis Delft.
- Steggewentz, J.H. en B.A. van Nes (1939) – Method of calculating the yield of a well, taking account of replenishment of the ground water from above, IASH.
- Verruyt, A. (1970) – Theory of ground water flow, London.
- Visser, W.C. (1958) – De landbouwwaterhuishouding in Nederland, COLN-TNO.
- Vogel, J.C. (1967) – Investigations of ground water flow with radiocarbon Symp. Isotopes in hydrology, IAEA.
- Wesseling, J. (1959) – The transmission of tidal waves in elastic artesian basins, ICW Techn. Bulletin 3, Wageningen.
- Wesseling, J. – in Versl. en Med. Cie Hydr. Ond. TNO nr. 5 (1960), nr. 15 (1969).