APPENDIX

A synthesis of:

SALT WATER INTRUSION MEETINGS 1968-1981

A review by

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1. INTRODUCTION

It was no mere coincidence when in 1968 hydrologists of two countries, where the theories on seawater encroachment originated, joined in an informal meeting. Indeed salinization of groundwater has been an ever lasting problem in the Nertherlands and along the German North Sea coast. This meeting was to become the first of a series of biannual symposia, during which scientists interested in this field of hydrologic research exchanged their experience.

The proceedings of the first three meetings successively held at Hannover, Vogelenzang and Copenhagen mostly contained a summary of the communications. From the fourth SWIM in Ghent on, papers were published in full. The proceedings of the latest two meetings were issued as a volume of series of international standing.

In 1981 at the seventh SWIM in Uppsala Prof. J.C. van DAM suggested to review all papers presented at previous meetings. The growing score of younger hydrologists, which entered this field of research, may benefit from earlier experience and thus further the state of knowledge by expanding on it.

This review contains some information, abstracts ([1]) and the bibliography of the seven SWIM.

For the first three SWIM rather extensive abstracts in English have been made. For later SWIM authors' abstracts and summaries, when available, have been included.

([1]) The complete text of the review including the abstract of all the seven SWIM papers may be asked directly to the author of the review.

2. ATTENDANCE AND PROCEEDINGS

Since 1968 scientists from 13 countries have attended the salt water intrusion meetings (table 1). The number of communications has more than doubled since the first meeting.

TABLE 1 – Attendance and papers presented at SWIM.

SWIM / Country	1	2	3	4	5	6	7
German. Fed. Rep.	16	11	2	4	4	40	7
The Netherlands	3	12	6	11	11	13	14
Denmark	1	2	9	3			1
Belgium		5	1	17	2	2	2
United Kingdom			1	1	22	2	
Sweden					2	2	18
France					1		
Italy						4	4
Spain						1	1
Poland						1	1
India						1	
Canada							1
Czechoslovakia							1
Participants	20	30	19	36	42	66	50
Papers	9	11	9	12	14	14	22

The proceedings have been listed below. Each volume is followed by the name and the address of the person who can provide additional information relating to the meeting and the authors.

SWIM 1 (Hannover, 28-29 November 1968)

Versalzung des Grundwassers in Küstengebieten, Bericht über ein Kolloquium am 28 und 29 November 1968 in Hannover, Bundesrepublik Deutschland. Bundesanstalt für Bodenforschung, Hannover 1968
(out of order).

Prof. Dr. P. MEISER
Niedersachsisches Landesamt für Bodenforschung
Stilleweg 2
D-3000 HANNOVER 51
German Federal Republic

SWIM 2 (Vogelenzang, 13-15 May, 1970)

Expert-meeting on salinization of groundwater in coastal regions, Vogelenzag 13th, 14th and 15th of May 1970. Dutch National Committee for the Internazional Hydrological Decade, The Hague
(out of order).

Prof. dr. ir. J.C. van DAM
Delft University of Technology
Department of Civil Engineering
P.O. Box 5048
NL-2600 GA DELFT
The Netherlands

SWIM 3 (Copenhagen, 6-8 June, 1972)

Salt Water Intrusion Meeting, Copenhagen 6th - 8th June 1972.
The Danish National Committee for the International Hydrological Decade, Copenhagen 1972.

Mr. L.J. ANDERSEN
Danmarks Geologiske Undersøgelse
Thoravej 31
DK-2400 KØBENHAVN NV
Denmark

SWIM 4 (Ghent, 28-30 August 1974)

Fourth Salt Water Intrusion Meeting - Proceedings. Editor:
W. De Breuck, Ghent 1975. Ministry of Economic Affairs
Adm. Mines. Geological Survey of Belgium.

Prof. Dr. W. DE BREUCK
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State University of Ghent
Krijgslaan 281
B-9000 GHENT
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SWIM 5 (Medmenham, 4-6 April 1977)

Fifth Salt Water Intrusion Meeting, Medmenham England, 4-6 April 1977.
International Hydrological Programme, England 1978.

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SWIM 6 (Hannover, 15-18 October 1981)

Sixth Salt Water Intrusion Meeting in Hannover 1979. Geologisches Jahrbuch, Reihe C, Heft 29, Hannover 1981. Bundesanstalt für Geowissenschaften und Rohstoffe und den Geologischen Landesämtern in der Bundesrepublik Deutschland.

Prof. Dr. P. MEISER
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SWIM 7 (Uppsala, 28-29 May, 1981)

Intruded and relict groundwater of marine origin. Proceedings of Seventh Salt Water Intrusion Meeting. Sveriges Geologiska Undersökning, Rapporter och Meddelanden nr. 27, Uppsala 1981.

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3. PAPERS

During the seven meetings more than 90 papers have been presented. A great diversity of topics has been covered. One could classify them in six broad categories:

General descriptions of problems and surveys
Regional comprehensive studies
Mathematical calculations and modelling
Methods and instruments
Hydrochemical investigations, including dating and isotopes
Geophysical investigations.

3. 1. General descriptions of problems and surveys

As many as 24 papers have given a general description of the problems and the surveys in salinized areas. W. RICHTER [62], and H. GERHARDY [29] have given a general review of salinization problems in Lower Saxony, G.F.R.. The salinization in the Netherlands have been reviewed by J.C. van DAM [75] with

particular reference to geo-electrical prospecting. T. COUWENHOVEN [15] has reported on the causes of salinization and the measures to be taken to correct the situation. The salinization processes in the aquifers of the Netherlands have received much attention. A.B. POMPER [56, 57, 58, 59, 60], J.A. BOSWINKEL [7], and J.J. de VRIES [22] have formulated hypotheses concerning the evolution of the process during the Quaternary epoch and under the influence of man. Salt groundwater situations have been described by L. ANDERSEN [3, 4]. M. GULINCK [33] has mentioned in general the fresh-/salt-water distribution in Belgium. R.A. DOWNING [23] has given a summary of saline intrusion problems in England. B. LEANDER [40], L. NORDBERG [50], H. LINDEWALD [43], J. SIN- DENVALL [70], and T. AGERSTRAND et al. [1] have explained the occurrence of saline groundwater in Sweden. V. COTECCHIA et al. [14] have treated the phenomenon and the evolution of seawater encroachment in a karstic and fissured limestone aquifer in Southern Italy. The seawater intrusion into aquifers in the Gdansk region in Poland has been explained by B. KOZERSKI [39]. I. RADHAKRISHNA [61] has given a general description of saline intrusion into the coastal aquifers of Orissa, India. B.Ch. SCHWERDTFEGER [68] has paid attention to a more special field of coastal hydrogeology, namely coastal springs.

3. 2. Regional comprehensive studies

Under this heading 23 papers haven been grouped, that relate the results of different field surveys, water analyses, dating and eventually modelling for a particular area. In nine of these models have been applied.

In the Wittmund area an extensive investigation has been carried out by a team of researchers. Results of the studies have been related by W. RICHTER et al. [63], and by H. DÜRBAUM [24]. E. BRANDT [8] has investigated the groundwater flow and the hydrochemistry of the Hattstedt polder. H. GERHARDY [30] has tackled the water supply problem on the island of Borkum. According to M. KLEEFELDT [38] and G. DELISLE & K. SCHELKES [21] groundwater salinity is being caused by the presence of a salt dome. The latter mentioned the use of numerical models for the simulation of the convection phenomenon.

K.D. VENHUIZEN [87, 88] has calculated the shape of the fresh-water lens under the dunes of the water catchment area of Amsterdam on the basis of boring data.

K. AMBO & Z. HAMAN [2] studied the unconfined chalk aquifer at Ålborg in Denmark by a geo-electrical survey and pumping tests.

W. DE BREUCK & G. DE MOOR [19, 20] have made an extensive investigation of the coastal area of Belgium. During an excursion to the eastern part [18] local conditions were explained. L. LEBBE [41] has based a mathematical model of the dune area of De Panne, Belgium, on a large field survey. L. LEBBE [42] has studied the fresh and salt water flow beneath the beach at De Panne, Belgium.

D.A. NUTBROWN [51, 52] has communicated the results of a very extensive study, including modelling, of the chalk aquifer of the South Downs, England. The fissured chalk aquifer on the south coast of England was also investigated by M. FLEET et al. [28]. Saline groundwater studies in the chalk of Lincolnshire have been related by J.W. LLOYD et al. [44] and D. EVANS et al. [26].

V. COTECCHIA [13] and T. TADOLINI & L. TULIPANO [72] have given an account of a very extensive investigation of a karstic aquifer in southern Italy.

The seawater encroachment near Barcelona, Spain, has been given much attention, as mentioned by E. CUSTODIO [16].

J.D. MATHER [46] has related the saline intrusion and the problems of groundwater development on the Pacific atoll of Tarawa.

3. 3. Mathematical calculations and modelling

A vast number of papers have been devoted to the mathematical approach and modelling of the salinization problem. Of the 33 papers presented 13 were more or less applied to a particular area. The other 20 dealt with a theoretical situation. The Dutch contribution to this aspects of SWIM has been overwhelming: 22 papers have been presented. The more theoretical aspect of fresh-/salt-water relationships was covered by J.C. van DAM [76, 77, 78, 79, 80, 81, 82], G.A. BRUGGEMAN [9, 10, 11], H.M. HAITJEMA [36], N.M. OBDAM [53], J.H. PETERS [54], H.C. ten HOORN [73, 74], C. van den AKKER [83], P. van der VEER [84, 85], C.J. van DUYN [86], and A. VERRUYT [89].

A model of mingling by displacement in dual porosity media, applied to a particular situation, was presented by R. BIBBY [5].

The use of Hele-Shaw models to determine the optimal pumping regime in coastal aquifers in Britain was presented by G.P. JONES and B.A. MEMON [37].

3. 4. Methods and instruments

Nine papers have been devoted to the description or the use of a method or an instrument for investigating salt water intrusion.

Aspects of the interpretation of resistivity soundings have been covered by H. FLATHE [2], J.J. MEULENKAMP [48], W. DE BREUCK [17], J.P. CNUDDE [12].

F. WALTER [28] has proposed the application of permanent electrode systems for groundwater salinity measurements. F. WALTER [91] also demonstrated geophysical logging equipment.

K. SENGPIEL and P. MEISER [69] have reported their experience with airborne electromagnetic resistivity mapping.

C.F. MÜLLERN and L. ERIKSSON [49] have tested VLF-resistivity measurements for locating saline groundwater.

R.A. SCHUURMANS and C. van den AKKER [67] have presented the results of a test to remove intruded saline water.

3. 5. Hydrochemical investigations, including dating and isotopes

Apart from the comprehensive studies in which some hydrochemical aspects have been covered, 10 papers have presented the results of extensive hydrochemical studies, dating and isotope distributions.

M. PETERSEN et al. [55] have investigated the calciumchloride ratio in the coastal groundwater in Schleswig-Holstein. J. HAHN [34, 35] has proposed a hypothesis about the evolution of coastal salinization in the Wittmund area of East Friesland based on chemical analyses, dating and measurements of the stable isotopes. The salinization phenomena in the Elbe valley were explained by E.P. LOEHNERT and. A. PALUSKA [45].

A.J. ROEBERT [64, 65] has formulated a hypothesis concerning the salinization phenomenon in the Amsterdam dune water catchment based on chemical analyses of groundwater samples. C.R. MEINARDI [47] has explained the hydrochemistry of salt groundwater in the Netherlands.

The presence of salt water in wells in Sweden has been analysed and explained by P. ENGQVIST [25], B. SUND & G. BERGMAN [71] and G. GIDLUND [32].

3. 6. Geophysical investigations

Three papers are entirely dedicated to resistivity surveys in a particular area. H. GERHARDY and J. FRITSCH [31] have investigated the salinization problem near Emden in East Friesland. O. RÜLKE [66] has located the fresh-/salt-water interface on some East Frisian islands.

R.H. BOEKELMAN [6] has made a resistivity survey in the «Groot Mijdrecht» polder in the Netherlands.

4. SUGGESTIONS FOR FUTURE COMMUNICATIONS

In general one can state that often a gap between practice and theory remains. Interesting models have been proposed but have not been applied in practice. On the other hand interesting field investigations have not been exploited to their full extent. Hence SWIM contributions could promote an international cooperation between field investigators and laboratory researchers between theoricists and practitioners. Exchanges have already taken place but could be extended to real team work.

As suggested at the Uppsala SWIM in 1981 field techniques and methods could receive more attention. The combination of different field methods may provide a better understanding of the dynamic processes. Experiences with new tools and techniques could stimulate and generate research in other areas.

Since resistivity soundings do not always distinguish between salinity and lithology, it may be useful to look for complementary geophysical methods. Although much research has been devoted it, the definition of the geo-electrical interface in terms of quality change still needs further precision.

In hydrochemistry one may try to find methods to better evaluate dispersion and diffusion phenomena in changing lithological and geological conditions. As has been pointed out a more general use of the Piper diagram may facilitate the exchange of ideas on the process of seawater encroachment, the mixing of waters, the physico-chemical processes between groundwater and rock. Improvement and standardization of sampling techniques may be another subject of future meetings. The experience with and the limitations of radiocarbon and other dating methods as well as other isotope techniques for salinization problems may provide another topic of discussion.

It can be expected that modelling of flow and quality changes will take an ever increasing part of future SWIM. It would be interesting to communicate their validity for actual field conditions.

Last but not least mapping and cartographic representation could also claim for some time in future meetings.

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