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ENVIRONMENTAL MANAGEMENT OF
AGRICULTURAL WATERSHEDS
Summary Report of a Conference
organized by IIASA and the
Czechoslovak Academy of
Sciences

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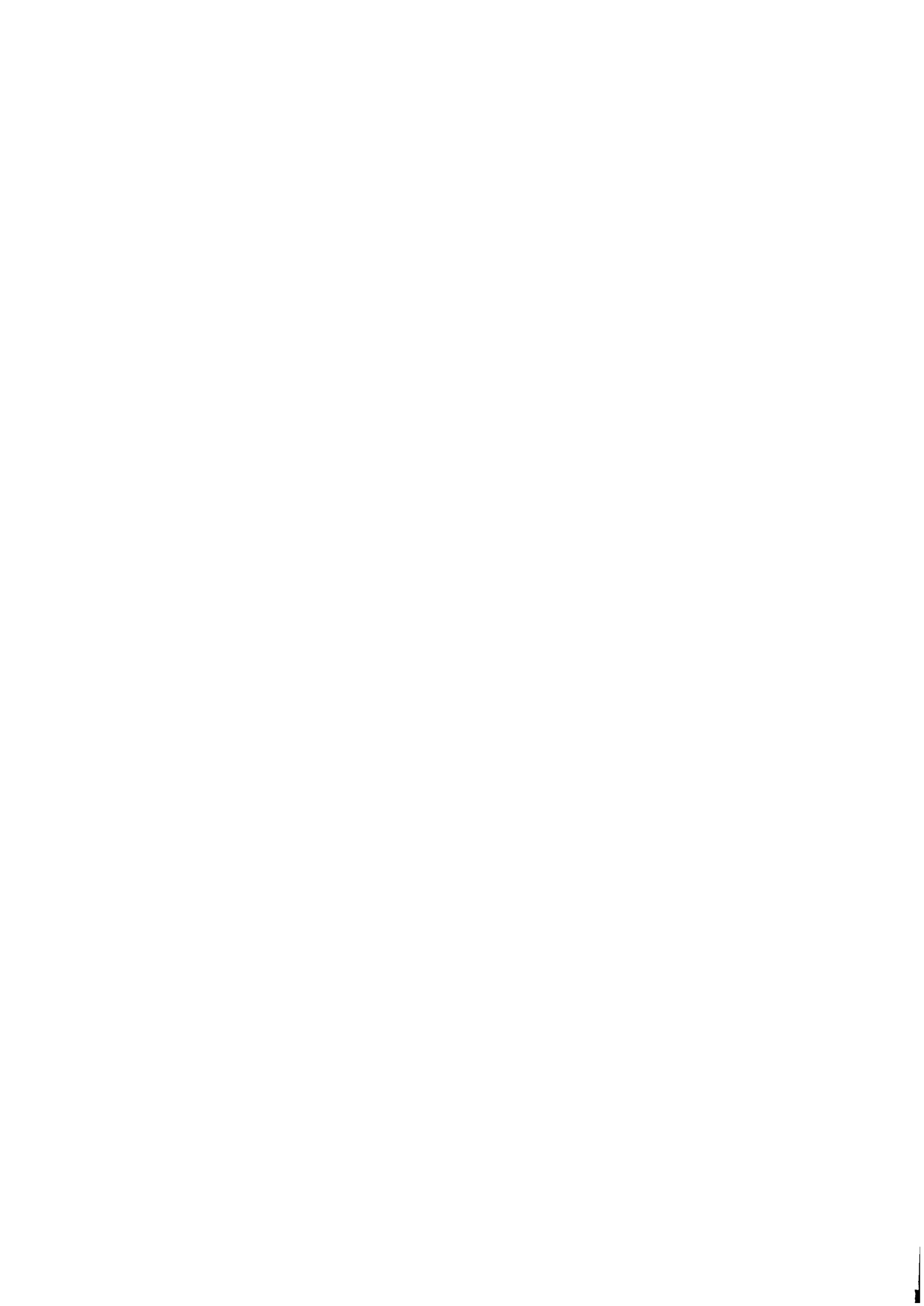
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PREFACE

In 1978, IIASA initiated a task on "Environmental Problems of Agriculture", a joint effort between the Food and Agriculture Program and the Resources and Environment Area. As one line of the task's activity, a conference on "Environmental Management of Agricultural Watersheds" was organized jointly by IIASA and the Czechoslovak Academy of Sciences. It was held in Smolenice, CSSR from 23-27 April, 1979.

A quarter of the world's surface is utilized for agriculture, therefore it is a major factor of man-made changes in the environment. Many of these changes have a strong feedback on agricultural production, while others influence the environment outside the agro-ecosystems. The objective of the conference was to exchange experiences in the active management of such changes. This short outline summarizes the principal findings presented at the Conference. The proceedings of the conference are in preparation and will follow shortly.

Professor Ferenc Rabar, Chairman, Food and Agriculture Program
Professor Oleg Vasiliev, Chairman, Resources and Environment Area



ACKNOWLEDGEMENTS

The authors would like to express their thanks to all those who contributed to this conference, whether by formal presentations, or through participation in the discussion. The authors are grateful to the chairmen and the rapporteurs of the sessions (see Appendix C), whose reports have been used in preparation of this paper. As the Chairman and the Deputy-Chairman of the organizing committee, we would like to thank the Slovak Academy of Sciences for having provided excellent facilities for the Conference and the members of the organizing Committee. Special thanks are extended to Dr. Juraj Pacl, who, as the principal organizer of the Conference from the host country, provided us with indispensable help. We are also grateful to Ms. Carolyn Fuhrmann and Ms. Caroline Goodchild for their technical and organizational help, and Ms. Anna John for editing the final version of the paper.



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INTRODUCTION

There are two principal ways in which agricultural production the world over can be increased: (a) by the intensification of use of existing agrosystems and (b) the development of unused land. Intensification of use means increasing the use of machinery, fertilizers and pesticides; development of irrigation, drainage, etc. This leads to a number of environmental effects, for example,

- (1) changes of physical/chemical properties of soil (in many cases these changes are unfavorable ones);
- (2) increased soil erosion;
- (3) pollution of surface and groundwater by derivatives of fertilizers and pesticides;
- (4) salinization of soils;
- (5) waterlogging;
- (6) increase of salt content in irrigation water, etc.

The fact that some land lies unused implies, in many cases, that the land is marginal in terms of agricultural value. Hence, one may expect unfavorable problems such as a high rate of erosion, a lack of drainage, high salt content in soil or irrigation water and so on. If uncultivated land was just less fertile than other lands nearby which are used for farming, it could be transformed into arable land by the use of chemicals, the development of irrigation and drainage, or other means by which intensive use could be made of the agro-ecosystem.

Increasing the agricultural output often leads to a number of environmental effects, mostly of unfavorable character. The effects which decrease the sustainability of an agro-ecosystem, have direct depressive feedbacks on agricultural production in

the short- or long-term. The effects which cause a deterioration in the quality of the environment of the agro-ecosystem in question, may not have a direct feedback on its agricultural production, but may affect agricultural output in a broader sense. Since society has a number of goals and agricultural production is only one of them, the need to maintain the quality of the environment limits agricultural activity.

Practical problems related to the environmental effects of agriculture depend very much on time and space. In terms of space, field level means that we deal usually with a zero or one-dimensional task, disregarding at least two spatial variables. At the watershed level, the spatial variation of factors and processes should be taken into account. Some approaches to the problem such as lumped parameter hydrological models, do not regard this explicitly; however, at the conceptual stage, the elements of space are contemplated.

Water plays an important role in linking various parts of the earth's surface, including agricultural areas. In a watershed, the total flow of water, together with the solutes and suspended solids, can be observed and controlled. Many problems of practical importance such as soil erosion, pollution of water bodies by agricultural chemicals, quality of irrigation return water, etc. can and should be managed at this level. On the other hand, some of the environmental problems are not obviously relevant at the watershed level, for example, management of quantity and quality of groundwater or secondary salinization of soils. However, the mere fact that groundwater and surface water are interrelated, makes it necessary to study and manage these problems at a watershed level as well.

Only some environmental impacts of agriculture have been planned and/or foreseen, but their overall consequences have a considerable influence on environmental quality in present day life, and for the life of future generations. The active management of such environmental changes is necessary. This issue has a marked systems character and leans toward the solution of applied problems. Therefore, IIASA, in cooperation with the CSSR Academy of Sciences, organized the Conference on "Environmental Management of Agricultural Watersheds" in April 1979.

The Conference was supported by several international scientific associations such as the International Society of Soil Science, the International Association for Hydraulic Research, the International Water Resources Association, the International Association of Hydrogeologists, the International Society of Ecological Modelling, as well as the Ministry of Agriculture of the Slovakian Socialist Republic and the CSSR Committee for IIASA.

The key issues discussed at the Conference were:

- (a) Physical fundamentals of the environmental problems in question;

- (b) The impact of agricultural practices on various aspects of environmental quality (evaluation, monitoring, forecasting - we had papers on both the experimental and modelling aspects of the issues).
- (c) Measures to control environmental quality, which in principle, are technological, economic, legislative, administrative, etc. (This conference was devoted mainly to the technological means of controlling the quality of the environment. But measures to control the situation can be elaborated on the basis of a study of the whole system).
- (d) Policies developed from the analysis of a system for better environmental management of agricultural activities.

These key issues were related to a number of topics:

- land use and its impact on water resources;
- agricultural management practices and their impact on water resources;
- management of groundwater for agricultural production;
- environmental management of irrigated agriculture;
- surface water quality in areas under fertilizer and pesticide usage;
- environmental management of complex agricultural systems.

Altogether, there were about 50 presentations. A majority of them will be published by IIASA in the Conference Proceedings. The purpose of this paper is to give a brief report on the Conference, while the proceedings are being prepared and printed. Each session had a chairman and rapporteurs. Their reports, edited and extended by the authors of this paper, have been widely used in the text which follows.

The opening session was chaired by Professor O.F. Vasiliev. Welcoming addresses were read by the following persons: Dipl. Ing. Eugen Németh, Deputy-Minister, Ministry of Agriculture, Slovak Socialist Republic; Dr. Roger Levien, Director of IIASA; Academician Oto Dub, Chairman of the Czechoslovak Committee for Hydrology; Professor Milos Holy, Immediate Past-President and President-Honoraire of the International Commission on Irrigation and Drainage (ICID); Professor Istvan Szabolcs, Deputy Secretary-General of the International Society of Soil Sciences; Mr. Josef Hladny, official representative of the World Meteorological Organization and Deputy-Director of the Hydrometeorological Institute, Prague; Professor Tibor Vasko, Chairman of the Czechoslovak Committee for IIASA. A welcoming address was received later from Dr. Shri K.K. Framji, Secretary-General of ICID. The texts of the addresses will be published in the proceedings.

O. Vasiliev, in his introductory talk, addressed the major general issues of the conference program, with particular emphasis on the importance of such basic interrelated concepts of hydrology as a watershed and a hydrological cycle. In approaching the problem of environmental management of a watershed, it must first be understood how the natural watershed system is affected by man's activities, including agriculture. Specifically, one must

compare the natural watershed hydrological cycle with the modified cycle which results from human activity. Both quantitative and qualitative changes in hydrological processes (including chemical runoff) must be studied.

G. Golubev (IIASA) discussed the reasons for choosing the subject of the Conference and its main objectives on the basis of a systems approach to the problem.

D. Pimentel (USA) stressed the seriousness of the soil erosion problem in the USA. Annual rate of soil erosion from agricultural land is 8 times greater than the natural rate of soil formation. A number of soil conservation practices have been elaborated and in certain regions they are especially effective. However, considerable energy inputs are required to carry them out.

The session on "Land Use and its Impact on Water Resources" focused on land use and agricultural and forestry management practices in relation to quantity and quality of water resources. Based on the study of water quality in several watersheds, M. Holy (CSSR) stated that there is an association between the intensity of agricultural production and the degradation of water quality. Reduced water quality depends on the amount of land in cultivation, the types of crops cultivated and soil conservation practices employed on the farms. Preliminary models have been successfully developed to relate pollutants in surface flows and water reservoirs to the amounts of fertilizers and pesticides applied in agricultural production. Effective agricultural land use practices and the replacement of pesticides with biological controls could significantly improve water quality.

An investigation of agricultural land use management and runoff of principal rivers of the USSR made by I. Shiklomanov (USSR) confirmed that several factors influence river flows. These include: the amount of water removed for irrigation of agricultural crops; the agricultural practices employed in crop production; and the extent of drainage of marshes and swamps. The irrigation of large agricultural regions in the USSR has resulted in significantly reducing the rate of runoff and flow from several rivers. The agricultural practices employed in the forest-steppe and steppe regions that are under 60-70% cultivation have resulted in reduction of surface flow from snowmelts. However, in this same area, surface flow and soil erosion have increased during heavy rainfalls.

V. Vanicek (CSSR) proposed that water may be used as an indicator of the ecological capacity of the rural landscape and integrity of the environment. He indicated that the ecological capacity of a region can be related to the abundance of natural resources, including water resources. Through "ecoengineering", it should be possible to utilize nature, water and other resources for the greatest benefit to man.

While conducting studies in developing countries, W. De Man (Netherlands) has attempted to describe environmental problems in watersheds dominated by agriculture. The complex management goals for each watershed are defined by the political leaders. Solutions are then designed to reach these defined political goals.

An investigation of the hydrological, hydrogeological and geochemical aspects of several small watersheds was carried out in the Czech-Moravian Hills of the Trnava River experimental basin by J. Balek, J. Skorepa, T. Paces and B. Moldan (CSSR). Important differences in volumes of surface runoff, subsurface outflow, and groundwater flow were reported for different vegetation patterns. In regions with vegetation, the major losses of water from these watersheds were from surface runoff and transpiration. The chemicals conserved and lost in forested and agricultural watersheds differed significantly. In both forest and agricultural watersheds, the elements conserved were S, P, Fe, and K, whereas the chemicals conserved in forests alone were Ca, Mg, Cl, and N. Chemicals lost from both forests and croplands were Na and Si.

H. Takehara's (Japan) studies demonstrated that agriculture in Japan uses about 70% of the total water withdrawn from rivers and other water resources. Forests were found to increase water infiltration rates compared with grasslands and forested areas which had been cleared. Water runoff rates increased 10-15% after deforestation. However, transpiration rates from forests were high and ranged from 400 to 1100 mm with rainfall that ranged from 1700 to 6000 mm annually.

In a general discussion guided by Chairman R. Keller (FRG), several major points were made: (1) Natural systems are too complex for mathematical modelling; (2) The simpler the model is, the more appropriate it is for understanding the dynamics of water resources in agricultural management systems; (3) Systems analysis is an appropriate technique for the synthesis and understanding of complex systems including the interrelationship of agriculture and water; (4) Synthesis of scientific information employing systems models should progress stepwise, that is synthesis, securing additional analytical data, followed by improved synthesis.

The session on "Agricultural Management Practices and their impact on Water Resources" started with a review paper by R. Keller (FRG). Out of a variety of human activities, agriculture is the strongest factor influencing natural water resources. A quarter of the land surface is influenced by man's agricultural activity. In historical retrospective, development of new arable lands caused an increase in soil erosion in various parts of the world. Major attention was paid to the comparison of annual runoff from forested and agricultural watersheds.

During the last decade, annual runoff in the world decreased because of an increase in evapotranspiration by 10%. The decrease of runoff was due to the substitution of natural forest vegetation

by arable lands and to increased yields. Effects of irrigation on water soil resources were discussed as well. It was stressed that it is necessary to study the impacts of agriculture on water resources in their relation to natural (geographical) conditions.

This last question was discussed in detail in the paper by A. Voronin, F. Zaidelman and L. Karpatchevsky (USSR) presented by A. Voronin. The main point of the paper is that environmental management is based on a deep understanding of the processes in a specific context. It is illustrated by drainage and irrigation measures in humid and arid areas respectively, of the USSR.

G. Hollis (U.K.) discussed three major problems of environmental management in relation to the hydrological regime in the United Kingdom: influence of afforestation, underground drainage of fields and nitrogen leaching issues. For the last 50 years, forested land in Great Britain increased from 2.5% to 8.5%, which thus reduced water yield. Area of underdrainage increased during the last 30 years by an order of magnitude which did not bring new flood problems and turned out to be quite beneficial in controlling the water table in some locations. Nitrate and nitrogen concentrations in rivers have risen, especially in S.E. England. The reason for the increase is not only fertilizer leaching, but also the change of natural conditions for the nitrogen cycle in and under the drained fields.

M. Kutilek (CSSR) discussed the influence of improper soil management on soil hydrology, specifically on infiltration, adsorption, formation of cracks and alkalinization.

P. Warmerdam (Holland) presented a paper on the effects of drainage on the hydrological regime based on measurements of a small watershed in Holland. The Wageningen Model II was used at first for parameter estimation on the winter data from the pre-amelioration period. Then the model was run with the data obtained after the drainage work had been carried out. The proportion between surface and subsurface runoff shifted towards the latter after the drainage measures were implemented.

In the discussion, environmental and ecological problems related to the main subject of the session were mentioned: loss of wildlife habitat due to conversion of areas with natural vegetation into arable lands, improvement of ecological conditions after implementation of irrigation on arid lands, etc. Participants stressed that there still exists a need to document many additional field studies which describe man's impact on water resources and the environment as a result of agricultural activity.

The session on "Management of Groundwaters for Agricultural Production" examined the interrelationship between agriculture and groundwater. The impact of agricultural practices on groundwater quality was a topic of major interest; some speakers looked at the effects of high groundwater levels on agriculture. Several mathematical models for groundwater were discussed and research needs were identified in some papers. In the area of groundwater,

quality deterioration because of agricultural practices and nitrate pollution, received much attention. C. Young (United Kingdom) showed the disturbing rise in nitrate levels in groundwater in the Chalk and Bunter Sandstone. He reported on an extensive program of drilling and sampling from these aquifers beneath arable, improved grassland, unimproved grassland and recently ploughed grassland. Water moves relatively slowly through the chalk and the uneven distribution of nitrate reflects different rates of leaching. Nitrate levels were much higher beneath arable land than pasture, but a big peak of nitrate could be related to periods when grassland was tilled.

B. Novak (CSSR) related nitrogen loss from the soil to the doses of nitrogen fertilizers. J. Hrasko, A. Mosik, O. Sustykevicova and T. Repka (CSSR) found the rate of nitrate leaching depending to some extent upon the rate of fertilizer use, ill-timed applications of fertilizer, improper application of irrigation water and the absence of organic fertilizers.

J. Vavra (CSSR) reported on a particularly thorough and comprehensive range of plot experiments with various fertilizers and agricultural practices. Several proposals were made for the management of nitrate in groundwater. J. Stredansky, J. Benetin, and J. Antal (CSSR) emphasized the need to keep large animal farms away from sensitive groundwater recharge areas. He and Novak also stressed the use of organic fertilizers, such as manure and compost, as a means of improving soil structure and immobilizing nitrogen in the soil.

C. Young said that little could be done once the nitrate had entered the unsaturated zone, but scavenge pumping, artificial recharge of low nitrate water or the treatment of borehole discharges might be attempted.

Other papers in the area of groundwater quality were those by N. Senesi and M. Polemio (Italy) who presented very comprehensive analyses of trace element concentrations in inorganic fertilizer. M. Maly and J. Salek (CSSR) examined the effects of irrigation with wastewater and septiced sewage sludge. The positive effects of the latter were the enrichment of the soil profile in humic material, nutrients and trace elements. Negative effects were observed after overdoses of wastewater, the most serious problem being the leaching of nitrates, sulphates and sodium.

Several mathematical models for groundwater movement were presented, but some of them were still at a formative stage, and only a few reports of their testing or application were given. The work of J. Czyzewski, M. Furmanska, M. Nawalany and E. Trykozko (Poland) was at a particularly early stage. Models by S. Antontsev, O. Vasiliev, S. Rybakova, V. Sabinin (USSR) as well as by J. Quast and H. Diersch (GDR) were very extensive and detailed, but they did not report on the testing or application of their models. In contrast, I. Mucha, P. Pospisil and L. Melioris (CSSR) used a three-dimensional model to calculate the layout and depth of well fields to maintain the water table at a suitable level for agriculture. C. Young used a very simple

model for the downward migration of nitrate in the unsaturated zone. He tested the model against tritium profiles and the results of redrilling a sample site after a three year period. He found that he could simulate quite adequately the rising level of nitrate in groundwater and was able to make disturbing forecasts for the future.

The papers by G. Kovacs (Hungary) and J. Benetin (CSSR) set out the requirements for future research. In general, they were pleas for us to view the hydrological cycle and agriculture as an interrelated system which operates in both time and space.

The general conclusions that may be drawn from the session are fourfold:

1. Mathematical models are successful when their testing and application leads to satisfactory performance and useful conclusions. Untested mathematical elegance is no substitute for an approximate, but working model.
2. Farmland and arable land, in particular, can pollute groundwater with nitrates. Heavy dressings of inorganic nitrogenous fertilizer, excessive irrigation with sewerage sludge and the ploughing of grass or legumes are important sources of non-point source pollution by nitrates.
3. Control of land use and the concentration of livestock in selected locations, is one way to protect groundwater from pollution by nitrates. A switch towards more extensive use of organic fertilizers (manure and compost) rather than inorganic nitrogenous fertilizer, would also have the effect of reducing nitrate leaching.
4. Once nitrate has entered the unsaturated zone, there is very little that can be done without further research into various methods of treatment.

In the session on "Environmental Management of Irrigated Agriculture", nine papers were presented. They may be divided into three groups. The first group consists of papers dealing with water pollution control in irrigated agriculture: (1) G. Skogerboe, G. Radosevich (USA) - Water Pollution Control Strategy for Irrigated Agriculture in the USA. (2) A. Hornsby (USA) - Management of Water Quality Impacts of Irrigated Agriculture. (3) P. Wierenga, C. Duffy, J. Hernandez (USA) - Effects of Irrigation on Return Flow Quality in the Rio Grande. (4) G. Skogerboe, W. Walker, R. Evans (USA) - Application of Salinity Control Planning Framework to the Colorado River.

From all these papers, it is evident that the environmental problems with respect to irrigated agriculture can only be solved within existing social and economic conditions. The problem of legal measures, therefore, has to be incorporated into influent quality control. The necessary conditions for such a control is the combination of the best water management practices and good agricultural practices. This will assure irrigation return flow quality control.

The second group presented papers devoted to the problems of salinization and alkalinization, which can be a limiting factor to the successful development of irrigation. They were: (1) I. Stepanov, A. Sabitova (USSR) - Control of the Melioration State of Irrigated Lands by Chemical Composition of Drainage Waters. (2) J. Szabolcs, G. Varallyay (Hungary) - Soil Salinity Problems in Watersheds. (3) L. Kadry (FAO) - Soilwater-salinity Relationship in the Hilla-Diwamiya (Iraq) Drainage Study.

The investigative approach to this problem was different. Some speakers discussed the origin and dynamics of salt movement on irrigated lands; the others concentrated their attention on the zoning of watersheds with respect to various degrees of hazard due to salinization and alkalinization. It is necessary to state that, when considering problems of salinity, soil and climatic conditions must be taken into account. The control of salinity in arid and semi-arid areas is different from that in subhumid and humid areas. The most effective measure for the control of salinity in arid and semi-arid areas is a purposeful combination of irrigation and drainage systems. In humid and semi-humid areas, attention should be focused on the water regime in the soil profile, and irrigation patterns must be considered from this point of view.

The third group of papers was comprised of mathematical models of water and salt movement in soils. They were: (1) S. Nerpin (USSR) - Physical Fundamentals of Mathematical Models of Water and Salt Transfer in Soils. (2) V. Penkovsky, V. Aemich (USSR) - Mathematical Models of Salt Motion in Soils. Soil may be investigated as a system where the processes of energy and mass transfer exist. Four levels at which this non-equilibrium system occurs were displayed. The phenomenological equation differs according to the relaxation time. The most complicated case of statistical thermodynamics for this process has to be considered when the relaxation time is commensurable for all the levels. Another approach may be based on the equation of convective diffusion and the kinetics of mass transfer between the movable solution and the soil/rock matrix, especially for salt transfer with nonlinear exchange kinetics.

As a conclusion to the problems of environmental management of irrigated agriculture discussed, it is necessary to state that the papers only covered them partially. Irrigation has a significant influence on the water regime, also from the quantitative point of view. Planned large irrigation systems require building of reservoirs, transfer of water--often over long distances--and other elements of water resource systems. They will have an important and increasing impact on the water regime in catchments.

It is also necessary to study other important environmental impacts of irrigation schemes; for example, changes in downstream water quality, ecological changes in the environment, micro- and mezzo-climatic effects of mass transfer of water, etc.

The chairman and the rapporteurs have recommended further IIASA activity to summarize the results and to cover thoroughly

the topics mentioned. This will help to create a comprehensive systems approach to all the important elements of irrigated agriculture systems, water resources systems, other environmental systems, and related issues. The aim of such a systems approach should be the best land use management securing the sound basis for solving environmental problems.

In the session on "Surface Water Quality under Fertilizer and Pesticide Usage", the wide range of papers provided many contrasting approaches to surface water quality in agricultural catchments. It was shown by D. Haith (USA) that similar conclusions had been reached by a number of North American studies examining large numbers of agricultural catchments for empirical relationships between characteristics of catchments and nitrogen and phosphorus losses. However, caution was urged in using the relationships obtained in management because of the problems in determining the importance of such characteristics as drainage density. The conclusion, however, that disturbed watersheds lose more nutrients than virgin areas was confirmed by subsequent papers and discussion centered on such varied areas as the Bohemian relict peneplain (V. Zajicek and B. Valek, CSSR), forested and agricultural catchments in the USSR (V. Kudeyarov and V. Bashkin, USSR), and nine watersheds in Italy (F. Massantini and F. Caporali, Italy). It was concluded that surface water nitrogen flows increase with the intensification of agriculture. However, agricultural methods used for particular crops can reduce the losses of nitrogen from the catchment. A clear example of this is the Italian vineyards where fertilizers are applied in the dry weather of late spring (F. Massantini and F. Caporali). Another relevant example is that of Czechoslovakia where contaminants were deliberately applied and their effects tested in percolation and/or seepage water.

Agricultural practice is subject to various constraints, and in Scandinavia, where the summer growing season is very restricted, many farmers continue to spread manure on frozen land. This causes very high losses and degradation of surface water quality. The situation in Finland is further aggravated by the vulnerable character of the surface waters which are oligotrophic with a high humus content (P. Valpasvuo-Jaatinen, Finland).

The problems of using empirical relationships based on imprecise data for management may be avoided by using simulation models. However, the dangers inherent in this approach were described and discussed with particular emphasis on the need for adequate calibration and validation of the model. It was stressed that models can only be expected to predict watershed performance for the type of system for which the model was developed. Several examples were given for applications in the USA and FRG (T. Lyons, USA) and Czechoslovakia (M. Holy, J. Vaska, K. Vrana, CSSR). In the latter example, a model was being used to evaluate quality in the catchment areas that supply drinking water to Prague.

Given the situation currently confronting rural society, namely that of the rising costs of energy and of fertilizers and pesticides which are essential inputs for increasing agricultural productivity, it is evident that these two factors will influence the course of future planning in the agricultural production sector. On the other hand, intensive fertilizer and pesticide usage pollutes water and therefore measures have to be taken to check the indiscriminate use of these pollutants for safeguarding and protecting the health and well being of rural and urban populations through setting minimum water quality limits. In this area of activity, modelling and the related field of applied systems analysis will exercise a decisive role in guiding the sound application of the comprehensive planning, monitoring, and control programs.

In the last session on "Environmental Management of Complex Agricultural Systems", there were four papers and a general discussion. D. Haith and R. Loehr (USA) presented a review paper on non-point sources pollution control. Emphasis was placed upon "best management practices" (BMPs) for control of non-point sources, rather than on the collection, treatment, and effluent standards approach. The BMPs are soil and water conservation practices (SWCPs), though their appropriateness must be carefully evaluated on the basis of the site-specific conditions. The SWCPs are not the best solution for all cases and all kinds of pollutants and there might be other alternatives, e.g., management of nitrogen fertilizer applications.

J. Bogardi (Hungary), W. Walker and J. Keuhner (USA) underlined the fact that the water quality problem is a multi-objective one and thus, it should be studied by methods of systems analysis. Two kinds of methodologies were presented: a system combining simulation models with a qualitative approach for the assessment of the socio-economic impacts of water quality changes, and a stochastic simulation approach. The problems of lack of appropriate data in general, and of uncertainties associated with model parameter estimates and climatic variations were stressed.

L. David (Hungary) presented an approach to study eutrophication of Lake Balaton based on the assumption that the degree of eutrophication is a function of regional and water management development on the watershed, natural characteristics of the sub-watersheds and location of a sub-watershed in the hierarchy of sub-watersheds and related parts of the lake.

In the paper presented by K. Frohberg (IIASA) and C. Taylor (USA), an attempt to develop a formal procedure for determining optimal soil loss was made. From the economic point of view, the optimal level of soil conservation can be obtained through maximization of the economic surplus, for both consumers and producers. A long-run dynamic optimization model was developed and run for various product demands, social time preference rates and soil loss coefficients.

In the general discussion, over 15 persons, including the authors of this paper, took part. The discussion can be summarized as follows:

1. The problems considered at the conference had many dimensions, and much interesting information concerning many elements of environmental management was presented.
2. Several papers were devoted mostly to the assessment of environmental effects of agriculture, which is just the first stage in environmental management. This perhaps reflects the situation with regard to the present state of the problem.
3. The main causes for environmental deterioration and the aims of land use management were stressed. Of these problems, water pollution through the use of fertilizers, especially nitrogen and phosphorus, was discussed. Appropriate measures for controlling agricultural and water resource systems that will be able to diminish this process were also discussed. The role of irrigation in semi-humid regions and the fact that it should be pursued hand in hand with the application of fertilizers was also mentioned.
4. The problem of environmental control of agricultural watersheds should be investigated from the standpoint of systems analysis. The systems approach to the problem provides the possibility of evaluating the trade-offs between agricultural development and environmental protection at various levels (including field, watershed, regional and national ones).
5. It was suggested that it would be desirable to organize a meeting not only of environmental scientists and water management engineers (including model builders), but to bring them together with model users and decision makers. Model users and decision makers will require guidelines for their actions and therefore, applied environmental programs are necessary, which would include, of course, the education of farmers. This process would require the active involvement on the part of economists, sociologists, lawyers, etc. In this respect, IIASA's role as a point of exchange of information may be very important and will aid in analyzing and solving control and management problems.
6. IIASA has thus promoted the exchange of experience and scientific knowledge among the participants of the conference and has advanced the basis for mutual cooperation in this field.

APPENDIX A: AGENDA OF THE CONFERENCE

SMOLENICE CASTLE, CSSR

APRIL 23-27, 1979

INTERNATIONAL CONFERENCE
ON
ENVIRONMENTAL MANAGEMENT OF AGRICULTURAL WATERSHEDS

AGENDA

Monday morning, April 23

Opening Session

- 10:00-10:15 Welcoming Address - J. Janovic, Minister of Agriculture, SSR
10:15-10:30 Welcoming Address - R. Levien, Director of IIASA
10:30-10:50 Addresses of Czechoslovak IHP Committee, WMO, ICID
10:50-11:20 O. Vasiliev, Deputy Director of IIASA and Leader of the Resources and Environment Area, (IIASA)
11:20-11:50 G. Golubev (IIASA), "Systems aspects of environmental management for agricultural watersheds"
11:50-12:30 D. Pimentel (U.S.A.), "Land use policies: Environmental degradation and energy resources"

Monday afternoon, April 23

Land Use and its Impact on Water Resources

- 14:00-14:40 M. Holý (CSSR), "Land use and its impact on water regime"
14:40-15:10 I. Shiklomanov, (U.S.S.R.), "Agricultural land use effect on river runoff"
15:10-15:25 V. Vaníček, (Č.S.S.R.), "Water as the dynamic indicator of the ecological valency of the rural landscape structure and integrity of its environment"
15:25-15:40 W. De Man, (Holland), "Some remarks on the element of space in environmental management of agricultural watersheds"
15:40-15:55 L. Rex, (U.S.S.R.), "Influence of agricultural land use on river runoff"
15:55-16:15 Coffee Break
16:15-16:30 J. Balek, J. Skořepa, (Č.S.S.R.), "Land use impact on the hydrological and hydrogeological regime of representative catchments of the Czech-Moravian Hills"
16:30-16:45 T. Pačes, B. Moldan, (Č.S.S.R.), "Differences between the runoff of eleven chemical elements from agricultural and forested watersheds"

- 16:45-17:15 H. Liebscher, (F.R.G.), "Results and experiences of studies in small watersheds on the influence of forestry and agriculture on the runoff regime of rivers in the F.R.G."
- 17:15-17:30 H. Takehara, (Japan), "Forestry management in its relation to agricultural practice"
- 17:30-18:00 Discussion

Tuesday morning, April 24

Agricultural Management Practices and their Impact on Water Resources

- 08:30-09:10 R. Keller, (F.R.G.), "The hydrological role of agricultural practices"
- 09:10-09:40 G. Hollis, (U.K.), "Man's effect on the hydrological regime in rural areas of the United Kingdom"
- 09:40-10:10 A. Voronin, F. Zaidelman, L. Karpachevsky, (U.S.S.R.), "Effect of agricultural activity on hydrological regime of landscape"
- 10:10-10:25 M. Kutílek, (Č.S.S.R.), "The influence of soil surface quality upon water regime of the region"
- 10:25-10:45 Coffee Break
- 10:45-11:00 P. Warmerdam, (Holland), "Hydrological effects of drainage improvement in the Hupselse Beek Catchment Area in the Netherlands"
- 11:00-11:40 D. Zachar, (Č.S.S.R.), "Ecological consequences of water erosion on watersheds"
- 11:40-12:30 Discussion

Tuesday afternoon, April 24

Management of Groundwaters for Agricultural Production

- 14:00-14:30 J. Benetin, (Č.S.S.R.), "Care for underground water regime in agricultural practices"
- 14:30-15:10 S. Antontsev, O. Vasiliev, S. Rybakova, V. Sabinin (U.S.S.R.), "Mathematical modeling of soil-and groundwater regimes"
- 15:10-15:40 G. Kovacs, (Hungary), "Flow and storage of soil moisture"
- 15:40-15:55 I. Ladunga, (Hungary), "AQUALIBRA 1.0: A model characterizing the occurrence of low soil moisture"
- 15:55-16:10 I. Mucha, P. Pospíšil, L. Melioris, (Č.S.S.R.), "Three-dimensional modelling of groundwater flow: a tool for solving groundwater problems in agricultural areas"

- 16:10-16:30 Coffee Break
- 16:30-17:00 C. Young, (U.K.), "The impact of agricultural practices on the nitrate content of groundwater in the principal U.K. aquifers"
- 17:00-17:15 B. Novák, (Č.S.S.R.), "The effect of fertilizers on the pollution hazard of water with nitrates"
- 17:15-17:30 P. Rijtema, (Holland), "The offset of grassland farming on nitrogen leaching"
- 17:30-17:45 N. Senesi, M. Polemio, (Italy), "Trace element contents of inorganic fertilizers and relative supplies to soils"
- 17:45-18:00 J. Středansky, J. Benetin, J. Antal, (Č.S.S.R.), "Complex of agrotechnical measures in agricultural utilization of soils in the protective zones of underground water sources"

Wednesday morning, April 25

Management of Groundwaters for Agricultural Production (continued)

- 08:30-08:45 J. Hraško, A. Mōcik, O. Šustykevičova, T. Repka, (Č.S.S.R.), "Some dependences between intensity of fertilization and amounts of nitrates in ground waters of the Zitny Ostrov area"
- 08:45-09:00 M. Malý, J. Šálek, (Č.S.S.R.), "Effects of irrigation with wastewater and septicized sewage sludges on the environment in agricultural watersheds"
- 09:00-09:15 J. Czysewski, M. Furmanska, M. Nawalany, E. Trykoźko, (Poland), "The concept of simulation model of the agricultural pollution in soil- and groundwater"
- 09:15-09:30 J. Quast, H. Diersch, (G.D.R.), "Use of confined aquifers for for underground storage of irrigation water, especially for infiltrated sewage"
- 09:30-09:45 J. Stibral, J. Vavra, (CSSR), "Underground Water Contamination with nitrogen"
- 09:45-10:15 Discussion
- 10:15-10:35 Coffee Break

Wednesday morning, April 25
(continued)

Environmental Management of Irrigated Agriculture

- 10:35-11:15 G. Skogerboe, G. Radosevich, (U.S.A.), "Water pollution control strategy for irrigated agriculture in the U.S.A."
- 11:15-11:55 I. Stepanov, A. Sabitova, (U.S.S.R.), "Control of the melioration state of the irrigated lands by chemical composition of drainage waters"

11:55-12:25 A. Hornsby, (U.S.A.), "Management of water quality impacts of irrigated agriculture"

Wednesday afternoon, April 25

Excursion

Thursday morning, April 26

Environmental Management of Irrigated Agriculture (continued)

- 08:30-09:00 P. Wierenga, C. Duffy, J. Hernandez, (U.S.A.), "Effects of irrigation on return flow quality in the Rio Grande"
- 09:00-09:15 G. Skogerboe, W. Walker, R. Evans, (U.S.A.), "Application of salinity control planning framework to the Colorado River"
- 09:15-09:45 S. Nerpin, (U.S.S.R.), "Physical fundamentals of Mathematical models of water- and salt transfer in soils"
- 09:45-10:15 I. Szabolcs, G. Varallyay, (Hungary), "Soil salinity problems in watersheds"
- 10:15-10:35 Coffee Break
- 10:35-11:05 B. Rozanov, (UNEP), "Management of water-salt regimes under irrigation in arid lands"
- 11:05-11:20 L. Kadry, (FAO), "Soilwater-salinity relationship in the Hilla-Diwamiya (Iraq) drainage study"
- 11:20-11:35 V. Bobschenko, (U.S.S.R.), "Water and salt balance control and groundwater regulation by means of drainage, agricultural engineering and reclamation methods"
- 11:35-11:50 V. Penkovsky, V. Aemich, (U.S.S.R.), "Mathematical models of salt motion in soils"
- 11:50-12:30 Discussion

Thursday afternoon, April 26

Surface Water Quality Under Fertilizer and Pesticide Usage

- 14:00-14:40 D. Haith, (U.S.A.), "Land use and water quality - a review of North American empirical studies"
- 14:40-14:55 A. Bredihina, V. Moskovkin, Yu. Yurkov, (U.S.S.R.), "Methodology to estimate transport of poisonous chemicals under intensive farming taking into account standards to protect water bodies"
- 14:55-15:10 V. Zajíček, B. Válek, (C.S.S.R.), "Water contamination by agricultural practices in penepain-type watersheds"

- 15:10-15:25 V. Kudeyarov, V. Bashkin, (U.S.S.R.), "The nitrogen balance in small river basins under agricultural and forestry land use"
- 15:25-15:40 P. Valpasvuo, (Finland), "Water-related environmental problems of agriculture in Finland"
- 15:40-15:55 F. Massantini, F. Caporali, (Italy), "Inorganic nitrogen contents of streams draining agricultural and forested watersheds in central Italy"
- 15:55-16:15 Coffee Break
- 16:15-16:45 V. Ladonin, (IAEA), "The behavior of herbicides in soil under different levels of fertilizer application"
- 16:45-17:15 T. Lyons, (U.S.A.), "Simulation of runoff quality from rural watersheds"
- 17:15-17:30 M. Holý, J. Vaška, K. Vrána, (Č.S.S.R.), "The deterministic model of nutrient transport at a catchment area level"
- 17:30-18:00 Discussion

Friday morning, April 27

Environmental Management of Complex
Agricultural Systems

- 08:30-09:10 D. Haith, R. Loehr, (U.S.A.), "The role of soil and water conservation practices in water quality and non-point source pollution control"
- 09:10-09:40 I. Bogárdi, (Hungary), W. Walker, J. Keuhner, (U.S.A.), "Assessing the water quality impacts of agricultural practices some methodological comparisons"
- 09:40-09:55 L. David, (Hungary), "watershed development approach to control the eutrophication of shallow lakes"
- 09:55-10:10 K. Frohberg, (IIASA), C. Taylor, (U.S.A.), "Optimal agricultural erosion-sedimentation control"
- 10:10-10:30 Coffee Break
- 10:30-11:30 Short reports of the chairmen and/or rapporteurs of the sessions
- 11:30-12:30 General Discussion
- 12:30 Close of the conference

APPENDIX B: LIST OF PARTICIPANTS

SMOLENICE CASTLE, CSSR

APRIL 23-27, 1979

INTERNATIONAL CONFERENCE
ON
ENVIRONMENTAL MANAGEMENT OF AGRICULTURAL WATERSHEDS

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26/4/1979

APPENDIX C: LIST OF THE CHAIRMEN AND RAPORTEURS

Smolenice Castle, CSSR

April 23-27, 1979

International Conference
on
Environmental Management of Agricultural Watersheds

Chairmen and Rapporteurs

MONDAY, 23 April - Afternoon

Land Use and its Impact on Water Resources

Chairman: Prof. Reiner KELLER (FRG)
Rapporteur: Prof. David PIMENTEL (USA)

TUESDAY, 24 April - Morning

Agricultural Management Practices and their
Impact on Water Resources

Chairman: Prof. Istvan SZABOLICS (Hungary)
Rapporteurs: Prof. Gaylord SKOGERBOE (USA)
Prof. Jan BENETIN (CSSR)

- Afternoon

Management of Groundwaters for Agricultural
Production

Chairman: Prof. John HERNANDEZ (USA)
Rapporteurs: Prof. Miroslav KUTILEK (CSSR)
Dr. George HOLLIS (United Kingdom)

WEDNESDAY, 25 April - Morning

Environmental Management of Irrigated Agriculture

Chairman: Prof. Milos HOLY (CSSR)
Rapporteurs: Mr. T. Clark LYONS (USA)
Prof. Franco MASSANTINI (Italy)

THURSDAY, 26 April - Morning

Environmental Management of Irrigated Agriculture
(cont'd)

Chairman and Rapporteurs: same as Wednesday
morning

- Afternoon

Surface Water Quality Under Fertilizer and
Pesticide Usage

Chairman: Dr. L.T. KADRY (FAO)
Rapporteurs: Prof. Sven JANSSON (Sweden)
Dr. Geoffrey MANCE (United Kingdom)

FRIDAY, 27 April - Morning

Environmental Management of Complex Agricultural
Systems

Chairman: Prof. Douglas HAITH (USA)
Rapporteurs: Ing. Zdenek KOS (CSSR)
Prof. Gyorgy KOVACS (Hungary)