

Water Demand A Selected Annotated Bibliography

**McDonald, D.G., Maidment, H.J. and
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**IIASA Research Memorandum
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WATER DEMAND
A SELECTED ANNOTATED BIBLIOGRAPHY

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August 1978

Research Memoranda are interim reports on research being conducted by the International Institute for Applied Systems Analysis, and as such receive only limited scientific review. Views or opinions contained herein do not necessarily represent those of the Institute or of the National Member Organizations supporting the Institute.

PREFACE

Interest in water resources systems has been a critical part of resources and environment related research at IIASA since its inception. As countries undertake more and larger projects to meet their water use, the physical limitations of natural water supplies are becoming apparent. This in turn requires an increase in the degree of detail and sophistication of the analysis, including economic, social, and environmental evaluation of development alternatives aided by application of mathematical modelling techniques, to generate input for planning, design, and operational decisions.

In the years 1976 and 1977 IIASA initiated a concentrated research effort focusing on modelling and forecasting of water demands. Our interest in this topic derives from the generally accepted realization that these fundamental aspects of water resources management have not been given due consideration in the past.

This report, the seventh in the IIASA water demand series, consists of a selected annotated bibliography on water demand literature which came about as a result of IIASA's study on water demands.

J. Kindler
Task Leader

ACKNOWLEDGEMENT

The research on water demands carried out at the International Institute for Applied Systems Analysis was partially supported with funds provided by Stiftung Volkswagenwerk and by Rockefeller Foundation grants RF75033, Allocation No. 32, and GANES 7712.

The authors wish to thank all the participants of the IIASA Workshops on Water Demands who contributed their many comments and suggestions, and to Jim Curry, Head of IIASA's Computer Services, for his help with the computer aspects of this bibliography. Also, special thanks are due to the 'father' of this project, Dr. Janusz Kindler, who remained patient and tolerant throughout this seemingly endless task.



Introduction

This selected annotated bibliography came about as a result of a study of water demands carried out during the years 1976-1978 at the International Institute for Applied Systems Analysis. A working draft of this report was presented to the participants of the "Second IIASA Workshop on Modelling Water Demands", held in Laxenburg, Austria, December 5-9, 1977, for their comments and suggestions (see Appendix I "Workshop Participants"). What is presented in this Research Memorandum then, is a synthesis of the working draft and these comments and suggestions. However, it should be stressed that this is a selected bibliography and is by no means exhaustive or complete. This project was envisioned as an ongoing project and as such was computerized to facilitate updating and periodic publishing, and as such it will be open to comments and suggestions through 1978. At that time this project will then be incorporated into a final report of the entire water demand task effort.

Therefore, this report should be viewed as interim with an open invitation to submit your suggestions on any aspect of this bibliography, as well as your suggestions for additions and/or deletions.

The major divisions or indexing in this report is achieved by the listings by title, author(s) and key-words, all of which refer to the serial index listing. As one can see, it is the serial index which is the complete entry for each article, i.e. title, author(s), reference, and abstract.

Located in the appendices (I & II), one can find; in appendix I, a list of the participants at the "Second Workshop on Water Demand" held in Laxenburg, Austria, December 5-9, 1977; and appendix II, which contains an expanded table of contents which, it is hoped, will make searching this bibliography as painless as possible.

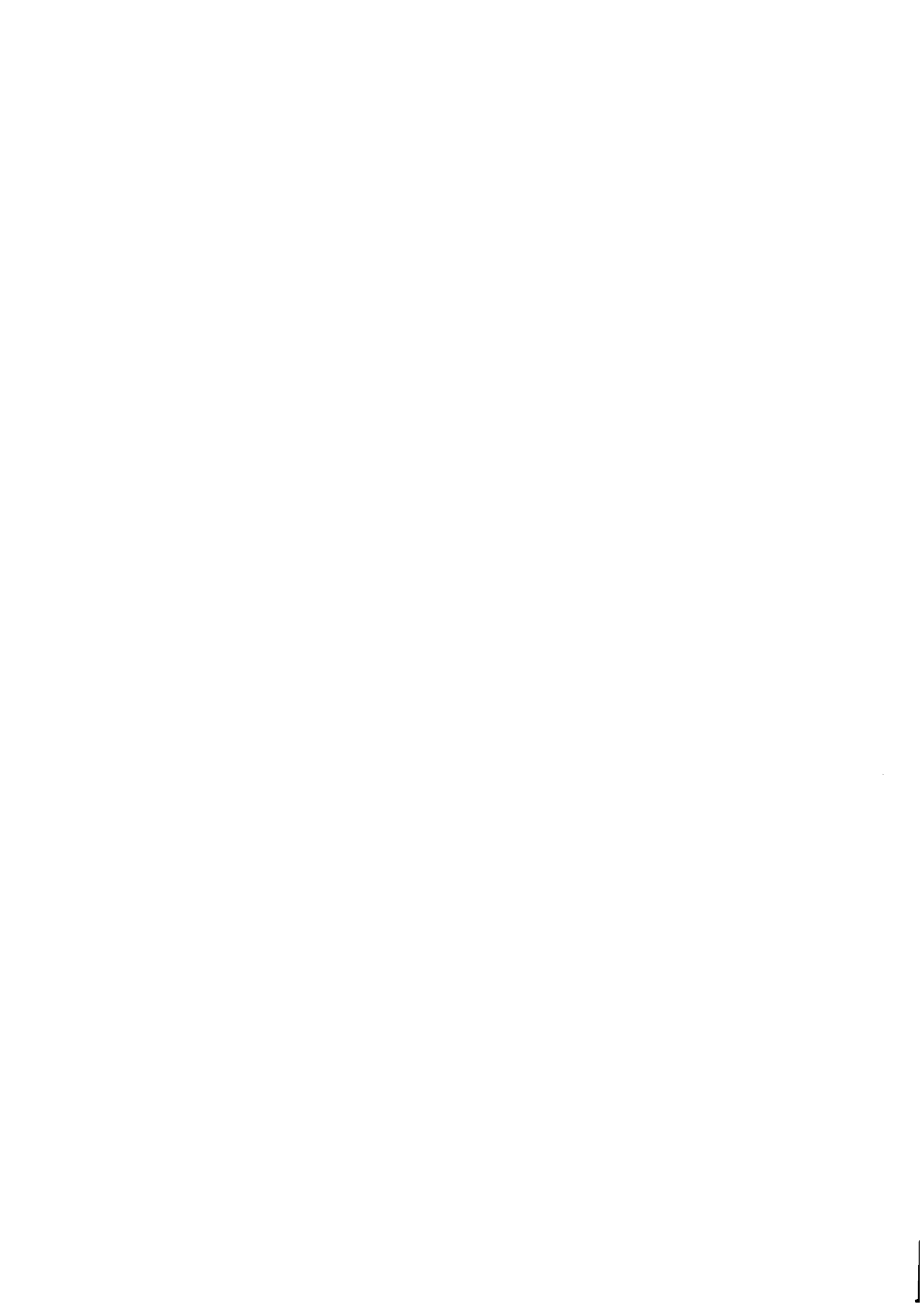


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S E R I A L
I N D E X

13-001

Hanke, S.H. Water Rates: An Assessment of Current Issues. Journal of American Water Works Assn. Vol. 67, No. 5, pp. 215-219, May 1975.

Scientific as well as philosophical bases for determining rate-making policies have been increasingly questioned by a wider cross section of professional and public interest groups, and the water-utility industry has begun to respond to criticisms of traditional rate policies. These trends have resulted in several fundamental changes that are more significant than any that have been made since the turn of the century. Acknowledging the new inclinations, this article focuses upon inquiries being made and the resulting responses.

Key words: Municipal, National, Pricing, Economics.

13-003

Mumy, G.E., S.H. Hanke. Public Investment Criteria for Underpriced Public Products. The American Economic Review, Vol. 65, No. 4. pp. 712-720, Sept. 1975.

Theoretical as well as practical developments in benefit-cost analysis have assumed that marginal cost pricing will be used in conjunction with standard evaluative and investment criteria. However, political and institutional realities often tend to support pricing at below marginal cost. In this paper the authors have developed evaluative and investment criteria appropriate for the cases in which public products are underpriced (for example, zero priced). The analysis suggests that benefit-cost analysis cannot be conducted independently of the pricing policy chosen to allocate an undertaking's capacity.

Key words: Municipal, National, Economics, Pricing, Social.

13-004

Ahlgren, N. Water in Human Settlements. Ministry of Housing and Physical Planning, Stockholm, Sweden, April 1976.

This paper focuses on the Swedish design of water supply and sewerage systems. Water consumption volumes, and the composition of waste water are given for industrial and domestic situations. Methods for water purification, sludge treatment, and water conveyance and the development of these methods from 1945-1975 are described. The environmental, legislative and administrative as-

pects are considered. Developmental trends in lake restoration and water supply, sewerage technology, and waste water management are also discussed.

Key Words: Municipal, National, Quality, Supply, Social.

13-005

World Bank. Village Water Supply. World Bank, 1818 H Street, N.W., Washington, D.C. 20433, U.S.A. March 1976.

This paper deals with the supply of water for domestic use in the rural areas of the developing world. Data are used to compare the costs of providing various types of water supply to rural villages and to show the effects of economies of scale as these villages increase in size. Regions which are considered are Africa, Latin America, the Caribbean, the South East Pacific and the West Pacific. Some of the specific countries examined are Algeria, Morocco and Turkey. An attempt is made to estimate the economic investment required to increase the percentage of these growing populations' access to different kinds of water supplies by 1980.

Key Words: Municipal, Regional, Supply, Social, Data.

13-006

Hanke, S.H., P.H. Carver, P. Bugg. Project Evaluation During Inflation. Water Resources Research, Vol. 11, No. 4, pp. 511-514, August 1975.

Rules for correctly dealing with price and interest rate projections when one conducts benefit-cost analysis during inflation are derived. Recommendations of the Water Resources Council and those adopted in the Water Resources Development Act of 1974 are critiqued. The use of real prices and real opportunity cost interest rates is recommended as an improvement over the present practice of employing real prices and nominal financial interest rates.

Key words: Municipal, Pricing, Economics.

13-007

Hanke, S.H. Demand for Water under Dynamic Conditions. Water Resources Research, Vol. 6, No. 5, pp. 1253-1261, October 1970.

An empirical analysis of the effects on residential water use of changing from a flat rate price structure to a metered one is presented. Time series data, for the first time, are used to study the dynamics of residential water demand. The results include the observations that: (1) sprinkling demands were reduced by the introduction of meters, with actual sprinkling being greater than the calculated ideal under flat rates and less than ideal under metered rates; (2) sprinkling use not only declined with the introduction of meters but subsequently continued to decline; (3) domestic demands (in-house) were reduced by 36% after meter installation; and (4) domestic demands stabilized at these lower levels. The evidence generated by the analysis demonstrates that water users do not return to their old use patterns

after meters are installed, and that metering results in a permanent and significant improvement in water use efficiency.

Key words: Municipal, Statistics, Economics, Pricing.

13-008

Hanke, S.H., B.T. Bower. Economic Aspects of Attaining Efficiency in the Use and Reuse of water. A paper presented to the United Nations' Panel of Experts on Waste Water Reuse, Tel Aviv, Israel, April 1974.

Water--for water supply and for disposal of residuals--is subject to the same basic economic laws as other commodities. Water prices must be accounted for when forecasting and designing water systems for residential, industrial and agricultural sectors. A number of case studies are reported in which time series data were analyzed to demonstrate that as price increases, the demand for water decreases.

Key words: Municipal, National, Economics, Quality, Data.

13-009

Howe, C.W., F.P. Linaweaver. The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure. Water Resources Research, Vol. 3, No. 1, pp. 13-32, First Quarter 1967.

This paper formulates models of residential water demand and estimates the relevant parameters from cross-sectional data. For the first time, it was possible to differentiate not only between domestic (inside) and sprinkling uses but also among metered, flat-rate, septic tank, and apartment areas. The major findings are: (1) domestic demands are relatively inelastic with respect to price; (2) sprinkling demands are elastic with respect to price, but less so in the west than in the east; (3) maximum day sprinkling demands, so important to system design, are inelastic in the west but relatively elastic in the east. The findings indicate that the elasticity of total demand, which this and other studies have found to be about -0.4 , is a weighted average of the domestic and sprinkling elasticities. Longer term adjustments to price are empirically investigated, and the role of demand functions in pricing and system design is discussed.

Key words: Municipal, Economics, Planning, Pricing, Supply.

13-010

Darr, P., S.L. Feldman, C.S. Kamen. Socioeconomic Factors Affecting Domestic Water Demand in Israel. Water Resources Research, Vol. 11, No. 6, pp. 805-809, December 1975.

Income, or its surrogate, has been an important predictor of residential water use. In the case of Israel, other socioeconomic variables not directly related to income have been found to be valid predictors and increase the sensitivity of residential forecasting models. For a sample of 1892 residences in Israel, aside from income those variables found to explain a significant portion of the variation in residential water use were number of

persons per family, cultural origin, education and age of the head of the household, and number of rooms per household.

Key words: Municipal, Statistics, Social, Economics.

13-011

David-Deli, M., M. Dulovics-Dombi. Forecasting Methods for Future Municipal Water Demands. Periodica Polytechnica, Vol. 16, No. 4, pp. 327-334, Budapest Technical University, Hungary, February 1972.

Methods for forecasting municipal water demands are divided into two categories: "mechanical" and "analytical". Mechanical methods are statistical extrapolations into the future of past trends in water demands. Analytical methods attempt to analyse the factors affecting the past trends, and thereby allow better forecasts of future water demands. Various methods in these categories are described in some detail.

Key words: Municipal, National, Statistics.

13-012

Hittman Associates Inc. Forecasting Municipal Water Requirements. In two volumes: Volume I. "The Main II System". and Volume II. "The Main II System Users Manual". A report submitted to the Office of Water Resources Research (now Office of Water Research and Technology), U.S. Department of the Interior, by Hittmann Associates, Inc., Columbia, Maryland, Vol I 212p., Vol II 434p., Sept 1969.

Volume I describes the research which resulted in the MAIN II SYSTEM. Also it is a technical report covering the earlier MAIN I System, which led to the development of the basic computational model. This study led to the development of three separate projection techniques for the water use parameters: utilization of existing forecasts; extrapolating local historical trends; and using growth models. The growth models were developed by extensive analysis of data from more than 50 Standard Metropolitan Statistical Areas (SMSA's) throughout the mainland United States.

The MAIN II SYSTEM was used to forecast water requirements for the city of Baltimore, Maryland, the new town of Columbia, Maryland, and the Baton Rouge, Louisiana, SMSA. Since these three forecasts have different growth characteristics they are useful in defining guidelines and approaches to be used in future applications of MAIN II. The results and conclusions from the forecasts, as well as discussions of the methods used, are presented in the report.

In Volume II, the Main II system computer program and the library of water usage coefficients, also required by the system, are described in detail and listed in appendices. Examples of data preparation and output reports are given. The user's manual also contains data regarding required computer characteristics and the specifications of the Main II system computer program and library magnetic tapes.

Key words: Municipal, Computer Program, Supply.

13-016

U.K. Central Water Planning Unit. Analysis of Trends in Public Water Supply. A report by the Central Water Planning Unit of the United Kingdom, Reading Bridge House, Reading, RG1 8PS, England, February 1976.

By fitting the relevant data to regression equations using time as an independent variable, linear trends are shown to very probably exist for metered water consumption, per capita unmetered water consumption and non-potable water consumption in various parts of England and Wales. Using these linear trends and population forecasts, the total water consumption in England and Wales is forecasted for the year 2001. However, such a forward extrapolation of past trends assumes that all factors influencing water consumption will continue to change in the future as they have done in the past. Which may not be a reliable assumption--especially in the case of metered consumption.

Key Words: Municipal, Data, Supply, Social, Economics.

13-017

Csuka, J. Methods of Forecasting Water Demands in Hungary. The National Water Authority of Hungary, June 1976.

Statistical methods for modelling and forecasting water demands are described. The theory of multi-variate regression analysis is developed and its various limitations are explained in detail. Approaches by which these methods can be applied to regional water demand forecasts are shown. A non-linear regression equation relating total water use in a country to its GNP, population and Irrigation development is developed and explained. The variation in water demands over a day is specified for several European cities.

Key words: Municipal, Statistics, Planning.

13-018

Sterling, M.J.H., D.J. Antcliffe. A Technique for the Prediction of Water Demand from Past Consumption Data. Journal of the Institution of Water Engineers (Great Britain), Vol. 28, No. 8, pp. 413-420, November 1974.

The paper considers the prediction of average monthly values of the total daily consumption of water in a mixed rural and industrial area in England. The method utilized requires only past consumption data making the technique more suitable, for implementation in an online control environment, than regression analysis involving meteorological parameters. The technique, which is based on spectral analysis, is shown to produce demand predictions within satisfactory operational requirements by comparison with the actual consumption over a period of several years in a mixed rural and industrial area in England.

Key Words: Municipal, Planning.

13-019

Owen, T.J., N.B. Morgan. A Water Consumption Model for the Central Water Planning Unit (of the United Kingdom). Scicon (Scientific Control Systems Ltd.) Sanderson House, Berners Street, London W1P 4AQ, England, 1976.

Models are investigated for the short-term forecasting (1-3 months) of water withdrawals from reservoirs. Monthly averages of daily data on water withdrawal, minimum and maximum temperatures, rainfall, and sunshine hours are used from 3 regions of the United Kingdom. The year-to-year linear trend in the withdrawal data is removed and then regression applied to estimate water withdrawal as a function of the weather variables. The resulting regression equations differed considerably from region to region. In addition, a simple regression model is derived relating the current month's withdrawal to that in the same month of the previous year. It is shown that this simple model gives a better fit to the data than the more complex one in two of the three regions studied.

Key words: Municipal, Statistics, Data, Supply.

13-020

Water Resources Bureau Japan. Creating a Water Resources Model. Water Resources Bureau, National Land Agency of Japan. A booklet distributed at the United Nations Water Conference, Mar Del Plata, Argentina, March 14-25, 1977.

A simulation model for forecasting water demands in Japan is described. Flow diagrams are given for each of the four sub-models; industrial, household, municipal and agricultural water demands. Some of the data and functional relationships used in these sub-models are also given. A number of exogenous variables are substituted into the model as given conditions. These variables include the rate of economic growth and pattern of water conservation. Values for these variables until the year 2000, are derived by extending past trends.

Key words: Municipal, Supply.

13-021

Reid, G.W., M.I. Muiga. Aggregate Modeling of Water Demands for Developing Countries Utilizing Socio-Economic Growth Patterns. A paper presented at the UNDP/UN Interregional Seminar on River Basin and Interbasin Development 16-26 Sept. 1975, Budapest, Hungary. Working Paper No. 48,

An aggregate model is described that predicts water demands in developing countries. The basic equations were developed using multiple regression analysis and are based on socio-economic parameters, such as population of the community, percentage of homes connected to water supply in the community and average annual income.

Key words: Municipal, Social, Economics.

13-022

Smith, R.J. Modelling of Water Demands and Waste Water

Discharges in England and Wales. International Institute for Applied Systems Analysis, RM 77-056, November 1977.

Traditionally, when preparing water demand forecasts in England and Wales, there has been heavy reliance on the forward extrapolation of present trends. For unmetered water consumption estimated regression equations could be determined for such trend equations be they linear or semi-logarithmic. For metered water consumption it was found that exponential and S-type curves fitted the past data well. Alternative methods for analyzing demand include; cross section, and econometric analyses. Cross section analysis seems severely limited by the lack of appropriate numerical data whereas econometric analysis has met with some degree of success. The present modelling situation for water demands for industrial water use domestic consumption, agricultural water demand and sewerage, sewage treatment, and effluent discharges are examined. It is concluded that in formal modelling work attention is focused on public water supply and household consumption rather than industrial water demand or the discharge of effluents.

Key words: Municipal, Statistics, Quality, National.

20-002

Swanson, E.R., A.V.S. Narayanan. Evaluation of the Effect of Alternative Agricultural Systems on Water Quality: A Linear Programming Approach. Chap. 33 in Spatial and Temporal Price and Allocation Models, by Judge and Takayama, North-Holland Press, pp. 676-687, 1973.

Agricultural activity may impair the the quality of nearby surface water. Linear programming is used to estimate the impact on the private sector of increasing the level of quality of the environment. The specific example used deals with estimating the consequences for private farm income of improving water quality in a reservoir by shifting to agricultural practices which reduce erosion. The land areas in each of the soil type-elevation-slope classes form a set of constraints on maximization of farm incomes. The additional constraint is the permitted level of annual sedimentation. This constraint is parameterized and the consequences on net farm income are estimated. The trade-off between farm income and sedimentation is thereby demonstrated.

Key words: Agricultural, Quality, Linear Programming.

20-003

Wu, I.P., A.M. Gitlin. Irrigation Efficiencies of Surface, Sprinkler and Drip Irrigation. Proceedings the second IWRA World Congress in Water Resources, "Water for Human Needs", New Delhi, India, Vol.1, pp 191-199, 16 Dec. 1975.

Overall irrigation efficiency can be found as the product of the efficiencies of distribution (areal uniformity) and application (water transpired / water applied). In surface irrigation an irrigation time of four times the advance time can produce a distribution efficiency as high as 95 percent. Sprinkler irrigation can achieve a uniformity coefficient of 80 percent or more if the

spacings are properly designed. Drip irrigation can achieve a 90 percent or more distribution efficiency if emitter flow variation is designed for less than 20 percent. The attainable application efficiencies of surface, sprinkler, and drip irrigation are 50-60%, 60-80%, and 90%, respectively. Methods for evaluating and comparing the irrigation efficiencies are presented and discussed.

Key words: Agricultural, Irrigation, Statistics.

20-004

Agarwal, M.C., R.F. Agarwal, R. Singh. Critical Evaluation of the Impact of Purported Improved Water Management Technology on Water Use Efficiency in Hissar District (Haryana). Proceedings of the Second IWRA World Congress on Water Resources, "Water for Human Needs", New Delhi, India, Vol. 1, pp 209-214, 16 Dec. 1975.

The development of irrigation facilities in India has been given high priority in the last 25 years. The irrigation area has doubled in these years. However, the crop yield increase has indicated that the management of the irrigation water needs to be more efficient. Crop yields per hectare are given for the major crops, and it is concluded that to obtain higher water use efficiency it would have been beneficial to increase the areas under grain, barley, rape and mustard as such crops have high production potential in terms of water used compared to other crop alternatives.

Key words: Agricultural, Irrigation, Planning, National.

20-005

Campbell, M.D., J.F. Buchheim, L.A. Brower. Wide Area Irrigation Scheduling for Efficient Use of Water. Proceedings of the Second IWRA World Congress on Water Resources, "Water for Human Needs", New Delhi, India, Vol. 1, pp. 215-224, 16 Dec. 1975.

A computer-supported irrigation scheduling program has been developed by the U.S. Bureau of Reclamation, to increase the effectiveness and efficient use of water over large areas. Irrigation scheduling as used in this paper implies timely application of specific amounts of water according to the variations in crop water requirements caused by weather changes. The irrigation scheduling entails frequent field visits for soil moisture verification and computer printouts of an appropriate irrigation schedule. The two different types of computer printouts which are used for these irrigation decisions are described. Data showing the percent improvement in crop yields in a region in Idaho with irrigation scheduling as compared to crop yields without irrigation scheduling is given.

Key words: Agricultural, Irrigation, Computer Program, Planning.

20-006

Onishi, H., E.R. Swanson. Effect of Nitrate and Sediment Constraints on Economically Optimal Crop Production. Journal of Environmental Quality, Vol. 3, No. 3, pp 234-238, 1974.

This is an analysis of crop systems and practices which are economically optimal in a 1,200 acre watershed with a planned recreational reservoir. For varying levels of water quality in the reservoir, linear programming is used to determine the optimum cropping sequences and their acreages, tillage methods and nitrogen application levels that are consistent with water quality standards pertaining to Nitrates, and sediment. Six combinations of restrictions on the choice of optimal crop systems were imposed and a system of charges for all sediment introduced into the reservoir was used. The study area chosen is the Forest Glen Watershed near Danville, Illinois.

Key Words: Agricultural, Linear Programming, Quality, Planning.

20-007

DeRidder, N.A. The Use of Models in Solving Agricultural Development Problems. Agriculture and Environment, Vol. 1, pp. 17-37, Amsterdam, 1974.

This article describes some recent developments in water resources management methods and water supply optimization techniques. Two models are discussed: a linear programming model for finding optimum solutions of water supply and a mathematical groundwater basin model, which is capable of simulating various extraction and replenishment flows and predicting the consequences of future engineering works. The unique feature of these two models is that the output of the linear programming model can be used directly on the groundwater basin model to test the physical validity of the economic solution. A case study in Iran is described.

Key words: Agricultural, Supply, Planning.

20-008

Voropaev, G.V. The Problem of Reducing the Share of Water Usage in Irrigation. Proceedings of the Second IWRA World Congress on Water Resources, "Water for Human Needs", New Delhi, India, Vol. 1, pp. 241-245, 16 Dec. 1975.

This paper reports the findings of a study in the USSR of irrigation development experiences in regions with limited water resources. Seven principles of optimum use of water resources formulated in the study are presented. They are: Supplying water to regions where the climate is such that the plant product per each volume of consumed water is high; selecting more valuable crops for irrigation; fixing the irrigation rates to get the highest increase of yield per unit of water consumed; improving plant breeding to the irrigated crops; using up-to-date irrigation methods; eliminating all waste losses in transportation; and using return water (effluent, drainage and filtration). The utilization of these principles ensures the decrease in specific water consumption per unit of product and the total increase in the efficiency of water consumption.

Key words: Agricultural, Irrigation, Planning.

20-009

Hooli, J. Irrigation in Finland. Symposium of the Technical Sections I and III of the CIGR, Cordoba, Spain, 18-24 April 1977.

Irrigation in Finland has increased since the beginning of the 1960's and therefore the need for forecasting water demand and for determining the irrigation/crop yield relationships has increased. These relationships can be determined using hydrometeorological data or irrigation experiments. Both of these methods, are discussed with reference to the Finnish situation together with the profitability of irrigation and the problems of securing irrigation water.

Key words: Agricultural, Irrigation, Supply.

20-010

Asopa, V.N., J.W.B. Guise, E.R. Swanson. Evaluation on Returns from Irrigation of Corn in a Sub-Humid Climate. Agricultural Meteorology, Vol. 11, pp. 65-78, November 1973.

The objective of the research in this article is: (1) to identify the best times for application of supplemental irrigation water so as to establish optimal operating policies; and (2) to examine the implied economic feasibility of investment in irrigation equipment. A weather-input corn-output relation is utilized as a basis for a dynamic programming analysis. The relation is also used to estimate the influence of moisture variables on corn yield.

Key words: Agricultural, Irrigation, Statistics, Operations Research.

20-015

Ijjas, I. Sprinkler Irrigation Application Package. Presented at the Ninth European Regional Conference of the International Commission on Irrigation and Drainage, (ICID), 1973.

This report summarizes work at the Institute for Water Management and Hydraulic Engineering of the Budapest Technical University, where an application package has been elaborated in the programming language ALGOL-60 for solving research, design and operation problems of sprinkler irrigation. The most important programmes of the package are as follows:

- a) A programme serving mainly research purposes:
 - design and optimisation of automatically generated regular pipe networks by means of dynamic programming;
- b) Programmes serving chiefly design purposes:
 - investigation of the sprinkling pattern of sprinklers situated in a regular network, simulation of sprinkler operation,
 - determination of the optimum diameters of a branching irrigation pipe networks by dynamic programming,
 - determination of the optimum diameters of a branching irrigation pipe network by linear programming;
- c) A programme serving mainly the investigation of operation problems:
 - hydraulic investigation of operation cases differing from the ones foreseen in the original design of existing branching irrigation pipe networks and simulation of operating irrigation installations.

Key Words: Agricultural, Irrigation, Computer Program, Planning.

20-018

Isyar, Y., C.V. Moore, G.W. Dean. Financial Analysis of Potential Agricultural Development on the San Joaquin Valley Westside. By the Giannini Foundation of Agricultural Economics at the University of California. R.R. No. 316, July 1971.

Linear programming methods are used to determine the cropping pattern which will maximize the economic returns to land and management resources for the irrigation projections (1970-1990) in the Westside of the San Joaquin Valley, in Southern California. The limiting factors are the price of water, the availability of irrigation water, the availability of soils of different quantities and the demand for the products of the project. It is shown that irrigating this region is a viable alternative from the financial repayment view, so long as speciality crop production is not sufficient to depress prices significantly and some reallocation of speciality crops among districts is made.

Key Words: Agricultural, Irrigation, Linear Programming, Economics.

20-019

Dean, G.W., H.O. Carter, Y. Isyar, C.V. Moore. Programming Model for Evaluating Economic and Financial Feasibility of Irrigation Projects with Extended Development Periods. Water Resources Research, Vol. 9, No. 3, pp. 546-555, 1973.

A multiperiod linear programming model of regional irrigation development is formulated and how the solution generates components required for project evaluation of economic and financial feasibility is shown. The model is particularly useful where the time path of development is critical; for example, in large projects where market restrictions for the products produced may permit only a gradual approach to full development over a long period of time. Applications of the model to a large-scale component of the California water plan show some deficiencies in past current planning procedures that may lead to difficulties in project repayment and create unforeseen negative welfare effects on nonproject producers.

Key Words: Linear Programming, Agricultural, Economics, Regional.

30-001

Bower, B.T. Studies of Residuals Management in Industry. From "Economic Analysis of Environmental Problems", ed by E.S. Mills, Columbia University Press, New York & London, 1975.

The studies of residuals generation in industry carried out over the last ten years by Resources for the Future are described. Industries studied include beet sugar, pulp and paper, petroleum refining, iron and steel, and coal-electric power generation. The method of analysis (simulation or linear programming), the

focus of the study and the source of information are given for each industry discussed. The economic impact of more severe antipollution policies is discussed and the potential of these studies to provide estimates of these impacts.

Key words: Industrial, Quality, Economics.

30-002

Bower, B.T. The Economics of Industrial Water Utilization. "Water Research" Ed. by Allen V. Kneese and Stephen C. Smith, Published for Resources for the Future, Inc., by The Johns Hopkins Press, Baltimore, pp. 143-173, 1966.

This study attempts to demonstrate that industry responds to economic factors in considering water utilization. Accepted investment criteria are applied in industrial investment decisions concerning water utilization systems within whatever constraints may exist, such as physical controls on effluents, technology, product output quality requirements, and input raw product quality. As the cost of water to industries increases, through increased intake water costs and increased waste disposal costs, the general reaction is to increase the extent of water recirculation. When the sum of waste treatment and intake water costs, becomes larger than the costs of closed cycle operation the latter will be adopted. It should be noted that in some cases, closed cycle operation is the minimum cost solution even where water intake and waste disposal costs are low.

Key words: Industrial, Planning, Economics.

30-003

Tate, D.M., R. Robichaud. Industrial Water Demand Forecasting. Social Science Series No. 10, Inland Waters Directorate, Water Planning and Management Branch, Ottawa, Canada, 1973.

A simulation model for industrial water demand forecasting is presented in this study. It was developed as a methodology useful to river-basin planners interested in formulating alternative development scenarios. In order to test the model data representative of 1960 conditions in the iron and steel industry were estimated, then forecasts were made for 1970 (a year for which real data are available). The forecasted data was felt to be in good agreement with the real data. The versatility, effects of policy, expandability, information requirements, sensitivity analysis of the parameters & constants and the limitations of the model are discussed.

Key words: Industrial, Data, Statistics.

30-004

Bower, B.T. Some Observations on Time Variations in Residuals Generation and Discharge. Presented at the Resources for the Future - World Health Organization Regional Office for Europe Workshop, Oct. 1974.

Residuals generation in industry is usually assumed to be steady-state. However, there are substantial variations in residuals generation and discharge over time. The different kinds of variation are described and four specific examples are presented: a) a dairy plant, b) a frozen products plant, c) a soap & detergent plant, and d) a linerboard mill. The implication of these time variations are also discussed.

Key words: Industrial, Quality, Economics.

30-005

Young, H.P., R.G. Thompson. Least-Cost Allocation and Valuation Model for Water Resources. "Water Resources Research" Vol. 9, No. 5, pp. 1186-1195, Oct, 1973.

A mathematical economic model of water use and water quality is formulated that allows for trade-offs between the technologies of water use and waste treatment and the capacities in different regions of the country for waste assimilation. The input-output coefficients of water-using production processes are written as functions of intake water quality so that the feedback effects of waste discharge on the economic process itself may be evaluated. The model determines the combination of production processes in each region that minimizes the over-all cost of meeting a given bill of final demands, including demands for water quality. Such a model could be used to evaluate water development projects on a consistent basis; in particular it would calculate the marginal values of water in different regions and the marginal costs of meeting different water quality objectives.

Key words: Industrial, Regional, Pricing.

30-006

National Institute for Water Supply in the Netherlands. A Study of Industrial Water Consumption in the Netherlands. A Quarterly Report by the National Institute for Water Supply in the Netherlands, No. 8, Jan. 1977.

The industrial water requirements in the Netherlands and the factors influencing them are examined in order to provide a base for forecasting water demands. Information has been collected for several industries on the amount of water used and how it is obtained (i.e. withdrawal from either ground or surface water or from public supply). The breakdown of total water consumption in the food, drink, and tobacco industry in 1972 is given. Also, attention is paid to specific water consumption per unit of product.

Key words: Industrial, National, Supply.

30-007

Davenport, F.S., S.P. Mathur. Management of Water Resources for Energy Development. Doc. No. E/Conf.70/TP 158, United Nations Water Conference, Mar Del Plata, Argentina, 14-25 March 1977.

The present water resources required for extraction and processing of energy resources and their conversion to usable forms of energy in the USA are examined in this paper. Together with Water demand forecasts for energy production in the years 1980, 2000 and 2020 are presented. The issues of managing water resources for energy uses are discussed under 3 categories; water supply, water quality and institutional (legal & economic) issues.

Key words: Industrial, Economics, Social, Planning.

30-008

Herrington, P.R. Water use in Fruit and Vegetable Processing in the UK. Progress Paper: A.5., United Kingdom Water Resources Board, Sept. 1971.

Water use in the UK fruit and vegetable preservation industry (FVP) is examined. The data presented are based on a survey conducted by FVP Research Association. Water demand estimates are derived for 1970-1980. The assumptions and relationships underlying these estimates are discussed. Only relatively modest increases in recirculation levels appear necessary to explain technically low or even zero future increases in the demand for water. Price was found to be a significant, although not large factor, in explaining variations in water intake per ton and in recirculation and therefore cannot be ignored when assessing future water demands.

Key Words: Industrial, Economics.

30-009

Whitman, W.E., S.D. Holdsworth, U.K. Central Water Planning Unit. Water use in the Food Industry. Research Report, British Food Manufacturing Industries Research Assn., Leatherhead, Surrey, England, Dec. 1975.

This paper is based on the results of a survey of water used in the food industry in Britain. The survey is extensive and covers 246 out of the 317 million tons of water per annum that the food industry is computed to use. Factories are grouped according to the foods they produce (e.g. milk products, potato products etc.). Then for each group of factories the total water use; tons of water/tons of product; type of water supplied (whether the water is taken from the main (potable water) or supplied from non-main (usually unpotable), or recirculated water (cooling towers); and the disposal methods for waste water are examined. The change in demand for 1974 compared to 1969 is used to forecast future water demand.

Key words: Industrial, Supply, Data.

30-010

Water Resources Board of the U.K., Textile Research Conference. The use of Water by the Textile Industry. Investigation Report, Textile Research Conference, Leeds, England, July 1973.

This paper reports the results of three separate investigations into the water demands of the textile industry in the UK. Three textile trade associations were involved: Shirley Institute, Wira and Hatra, coordinated by the Water Resources Board. Questionnaires were circulated to most of the firms that bleached, dyed or finished fabric or yarn, and these asked for volumes, costs and sources of water used, together with the total weight of textile materials that were wet processed. The results showed that specific water usage, in gallons per pound of goods processed, varied considerably and so too did water costs. Despite the basic similarities between the industries covered by the three research associations there are essential product, process and regional differences.

Key Words: Industrial, Data.

30-012

Calloway, J.A., R.G. Thompson. An Integrated Power Process Model of Water Use and Wastewater Treatment in Ammonia Production. PB# 237:221, National Technical Information Service, Silver Spring, Md., USA, July 1974.

A linear programming model is developed for evaluating the effects of effluent standards and costs of water withdrawals in representative ammonia plants located in Houston, Texas; Trenton, New Jersey; Saginaw, Michigan; and Sacramento, California. The following results were obtained: (1) zero discharges of suspended solids, heat, and total dissolved solids increased production cost by approximately 1.5% using injection well for ultimate disposal and 3.2% using evaporative disposal techniques; (2) zero discharges increase energy consumption by approximately 2.7%; (3) higher costs for water withdrawals do not significantly increase production costs; (4) effluent taxes required to achieve zero discharge vary with geographic location ranging from 20 cents/lb for Saginaw, Michigan, to 36 cents/lb for Trenton, New Jersey; (5) a water withdrawal price greater than 50 cents/MGal is necessary before air cooling becomes feasible in any location.

Key Words: Industrial, Quality, Linear Programming.

30-013

Calloway, J.A., R.G. Thompson. An Integrated Industry Model of Petroleum Refining, Electric Power, and Chemicals Industries for Costing Pollution Control and Estimating Energy Prices. Engineering and Process Economics, Vol. 1, pp. 199-216, 1976.

Linear programming models of typical plants for the petroleum refining, electric power, and chemicals industries are scaled up to the national level and integrated by means of the products exchanged between the respective industries. The resulting model is used for these industries to evaluate the effect on product costs of restrictive wastewater discharge standards.

Key Words: Industrial, Quality, Linear Programming.

50-004

Luken, R.A., D.J. Basta, E.H. Pechan. Water Pollution Control

Act of 1972, National Residuals Discharge Inventory. By the U.S. National Research Council for the U.S. National Commission on Water Quality, National Technical Information Service, Silver Spring, Md, PB-252 288, January 1976.

This book is a analysis of residuals (all pollutants) discharged into the environment, along with estimates of capital costs of constructing the necessary facilities for treatment of these residuals to various levels and the distribution of such costs by geographic region. Also included are analytical studies of the regional distribution of residuals likely to result from the implementation of the successive improvements in water quality set out in of the U.S. Federal Water Pollution Control Act Amendments of 1972.

Key words: Quality, National, Planning, Economics.

50-005

Gianessi, L.P., H.M. Peskin. Water Pollution Discharges: A Comparison of Recent National Estimates. A discussion paper from the Quality of the Environment Division of Resources for the Future, discussion paper D-2, Feb. 1977.

There are several estimates of industrial discharges available. This paper discusses three recent comprehensive studies of this type. The purpose of the discussion is to inform potential users of the fact that the various estimates differ from each other, often substantially. These differences and their reasons are discussed in some detail, as well as the methods and simplifying assumptions that are often obscured from the potential user.

Key words: National, Quality, Planning.

60-006

Prague Research Institute for Water Management. Methods for Estimating Water Demands and Waste Water Discharges. Prepared by the Research Institute for Water Management in Czechoslovak Socialist Republic, to appear as IIASA Research Memorandum, Int. Inst. App. Sys. Analysis, Laxenburg, Austria, 1977.

This is a report about the experience in the Czechoslovak Socialist Republic regarding their methods for estimating water demands and waste water discharges. Their experience evolved from a study based mainly on a partial task within the Water Management Orientation Plan - "Prognosis of the Future Water Off-take and Consumption in the CSSR till the year 2015". The objective of the task was to work up a prognosis of the future development of water-off take and consumption till the year 2015 based on the assessment of the prospective development in the area covering three sectors; Municipal, Industrial and Agricultural. Their methodology, results and suggestions for further study are discussed.

Key words: General, Statistics, National, Quality.

60-008

Lee, T.R. Approaches to Water Requirement Forecasting--A Canadi-

an Perspective. Social Science Series No. 9, Canada Centre for Inland Waters, Burlington, Ontario, 1972.

This is a description of how water planning activities and water requirement forecasting in Canada have developed outside a scarcity situation. The different methods used include a straight line projection based upon historical needs, correlation analysis and the development of estimating equations from the regression line, and the development of mathematical models. Two basic categories of river basin models are being developed, mathematical programming (linear and non-linear) and simulation models. The information availability, applicability and limitation of the different forecasting methods are discussed.

Key Words: General, National, Economics, Social, Supply.

60-012

United Nations Centre for Natural Resources and Energy and Transport. Report of the Meeting: Expert Group Meeting on the Achievement of Efficiency in the Use and re-use of Water. Herzlyah, Israel, U.N. Doc. No. 75-12494, 11-22 November 1974.

The efficiency in the use, and re-use, of water for agricultural, domestic and municipal, industrial, and energy purposes is examined. For each of these purposes, the following are discussed: a) The technical aspect - how efficient, in water use, are the present methods employed in agriculture, etc., and to what extent is water being reused; b) the economic and financial aspects - what effect on water planning policy should the fact that prices influence use and should beneficiaries of water resource projects pay in proportion to the benefits received; and c) the legal and administrative aspects.

Key Words: General, Planning, Supply.

60-013

ECE Committee on Water Problems, V. Plechac, G.D. Cobb, D. Huault, J. Pukacz. Principles and Methods for the Provision of Economic Incentives in Water Supply and Waste Water Disposal Systems. A report prepared under the auspices of the Economic Commission for Europe Committee on Water Problems. United Nations, New York, UN Doc. No. E.76.II.E.25, Oct. 1976.

The aim of this report is to highlight and analyse the main provisions of economic incentives in water resources management. The economic incentives in the fields of protection of water against pollution and rational water resource utilization are described, and the stimulation of investments in the development of water management is discussed. Examples for each of these three factors are provided from information received from a survey conducted to examine the economic incentives used for the protection and utilization of water resources by the individual 'Economic Commission for Europe' member countries.

Key words: General, Supply, Economics, Pricing.

60-015

U.S. National Water Commission. Forecasts and the Role of Alternative Futures. Journal of The Water Resources Planning and Management Division, Proceedings of the American Society of Civil Engineers, Vol. 102, No. WR2, pp. 365-383, November 1976.

A review of previous water resource forecasts by the Kerr Commission, the Water Resources Council, and the USGS is presented. Comparison among them indicate widely ranging figures depending on the underlying assumptions. Various factors affecting forecasts are presented along with conceptual problems in forecasting. Rarely have the impacts of alternative policy assumptions, life styles, or technological change been fully considered. Furthermore, forecasts are typically viewed as "requirements" rather than as "desires" which must be examined for their benefits and costs. Developing a single "most likely" forecast is rejected in favor of separate "alternative futures." Typical assumptions for various alternative futures are presented encompassing population growth and distribution, food and fiber production, income distribution, national economic efficiency, lifestyle changes, and various means of developing, using, and conserving water resources.

Key words: General, Planning, National.

60-020

Knoppert, P.L. Long Term Planning of Water Supply: General Report Number 1. Prepared by the International Water Supply Association, Amsterdam Congress 1976.

This is a general set of guidelines prepared from information and data supplied by nine countries (Belgium, Finland, Germany, Great Britain, Ghana, Japan, Netherlands, Russia and Spain) for instituting long-term planning of water resources. The systems of prognosis are examined including; linear, exponential and logistic extrapolation of trends, regression calculations (standard deviation, covariance and coefficients of correlation, method of least squares, and curved regression), systems analysis and modelling.

Key words: General, Supply, Statistics, Planning.

60-021

Weiss, A.O. National Water Assessment Procedures of the United States of America. Presented at the Economic Commission for Europe, Committee on Water Problems Seminar on Long-Term Planning, Bulgaria, U.N. Doc. No. Water/Sem.4/R.2/Com.7, 17-22 May 1976.

The U.S. Water Resources Council is conducting a three and a half year effort (began in 1975) to identify and describe the USA's severe water problems and establish priorities. The assessment seeks to evaluate two future time periods: Immediate problems (1975-1985); and Future Problems (1985-2000). The study comprises three major analysis steps: a nationwide analysis; an analysis of specific problems, including specifications of State-Regional viewpoints; and an analysis of national priorities. Each of these steps is discussed separately and the relationship between them is summarized in a flow diagram.

Key words: General, Planning, Supply.

60-022

Reynolds, P.J. Systems Approach to Regional Water Use and Demand. From the proceedings of the Fourteenth Congress of the International Association for Hydraulic Research, Paris, Vol. 5, pp. 293-300, 29 Aug - 3 Sep 1971.

This paper is the presentation of an argument for the adoption of the systems approach to assess the water use and demand in regional water management analysis. The author argues that the costs and manpower requirements required to collect and assess water use and demand data can be prohibitive, however, methods and techniques embraced in the systems approach appear to have significant relevance in providing water resource management with effective ways of improving investment decisions and forecasting alternative futures.

Key Words: General, Regional, Operations Research, Planning.

60-024

Young, J.A. General Report 2: Control of Water Supply Demand. A Report of the 11th International Water Supply Congress, Amsterdam, sponsored by the International Water Supply Association, London, Nov. 1976.

In this report the question "Why control water demand at all?" is raised. Several representatives from the membership of the International Water Supply Association, collaborating with the author, present a broad general answer to the question. Main discussion points regard technical methods of control, who uses what, and how effective are they. Also covered, is the need for education and publicity to effectuate tighter control methods and to reduce demand.

Key words: General, Planning, Supply.

60-027

Domokos, M., J. Weber, L. Duckstein. Problems in Forecasting Water Requirements. Water Resources Bulletin, American Water Resources Association, Vol. 12, No. 2, pp. 263-275, April 1976.

Methodological problems associated with forecasting water requirements by use of regression analysis are examined. Problems occurring when long-range forecasts are based on linear and non-linear extrapolation of time series models include possible changes in socio-economic conditions, water allocation system structure, and limits to growth. Problems arising in forecasting based on multiple regression models are likely to involve serially dependent errors, multicollinear explanatory variables, and difficulties inherent to the presence of explanatory variables that must themselves be predicted.

Key words: General, Statistics, Operations Research.

70-001

Grunewald, O.C., C.T. Haan, D.L. Debertin, D.I. Carey. Rural

Residential water Demand: An Econometric and Simulation Analysis. Water Resources Bulletin, American Water Resources Association, Vol. 12, No. 5, pp. 951-961, Oct. 1976.

This study proposes that demand management through pricing policies can be used in conjunction with supply management to solve water supply problems. Economic principles are shown to apply to rural residential water use. A demand function for water was developed based on cross-sectional water use data collected in Kentucky. Price was found to be a significant determinant of the quantity of water demanded. A constant price elasticity of -0.92 was found. The demand function was used in a simulation analysis to determine reservoir capacity needed to supply water needs of a rural community. The simulation revealed that price can significantly affect required reservoir storage.

Key words: Municipal, Supply, Operations Research.

70-002

Morgan, W.D., J.C. Smolen. Climatic Indicators in the Estimation of Municipal Water Demand. Water Resources Bulletin, American Water Resources Association. Vol. 12, No. 3, pp. 511-518, June 1976.

Three climatic or seasonal models are evaluated with an identical data set in order to compare which climatic indicators perform best. In general, Model I, using the readily available temperature and rainfall marginally outperform the climatic variable potential evapotranspiration minus precipitation (PE-R), Model II. Both of these models perform much better than the naive model using seasonal binary variables, Model III. The result for the naive model is understandable because it does not account for any climatic variation over the sample other than the gross differences between months. The more heterogeneous the sample, the poorer this particular naive model would predict water deliveries.

Key words: Municipal, Statistics.

70-003

United Nations Natural Resources Committee.. The Demand for Water: Procedures and Methodologies for Projecting Water Demands in the Context of Regional and National Planning. United Nations, U.N. Doc. No. ST/ESA/38, Sales No. E.76.II.A.1, New York, 1976.

The scope of this report include: (a) An outline of the conceptual and procedural frameworks for water demand forecasting as the basis of long-range planning for water resources and policy formulation (chaps. I and II); (b) review of basic methodological approaches and techniques applicable for forecasting the various categories of water demands and for comparing them with the available supplies in an integrated fashion (chaps. III to VIII); (c) review of indicative data on specific water uses and demands to facilitate tentative projections where local data is lacking or inadequate (annex I); and (d) recommendations for national and regional Governments, particularly in the developing countries, in establishing or strengthening the institutional frameworks and

the data base for assessing and projecting the demands for water (chaps. IX and X).

Key words: Regional, National, Planning, Statistics, General, Social.

70-004

Cluff, C.B., K.J. DeCook. Conflicts in Water Transfer from Irrigation to Municipal use in Semiarid Environments. Water Resources Bulletin of the American Water Resources Association, Vol. 11, No. 5, pp. 908-918, October 1975.

Conflicts caused through development of urban areas in proximity to irrigated agriculture in water-scarce regions can be minimized through the direct urbanization of irrigated lands. This shifts the water supply from one use to another on the same site rather than creating an additional use in an adjoining area. This condition has prevailed in the Phoenix region. In the Tucson region, the municipality is buying and retiring farmland in an adjacent agricultural area, for the purpose of acquiring the water right in order to transfer water to municipal use. This land purchase is necessitated by existing Arizona water law, which ties the water to the land. This method of transfer creates problems concerning how much water can be transferred per acre retired; what to do with the abandoned farmland; inequities to agribusiness and taxing entities; and loss of food crop production which have not been resolved. An alternative to the retirement of farms, applicable in the Tucson region, is to exchange treated municipal wastewater for irrigation water. While this method appears to be the least disruptive, it requires the resolution of certain institutional problems.

Key words: Supply, Irrigation, Municipal, Recycling.

70-005

Walker, W.R., G.V. Skogerboe. An Implicit Approach to Pricing Agricultural Water Transfers to Urban Uses. Water Resources Bulletin, American Water Resources Association, Vol. 11, No. 4, pp. 751-758, August 1975.

The increased agricultural efficiency of the American farmer has been a substantial impetus to this nation's rapid urbanization. In many western regions where total water supplies are limited, urbanization has required the transfer of heretofore agricultural water rights to the urban use. A major problem in such transfers has been the value or price of the water. A management level model of a typical urban water system was developed to optimize water supply, distribution, and wastewater treatment alternatives. The values of agricultural transfers were determined as the cost of a downstream right. This procedure is justified by the economic theory of alternative cost. Results for a test application to the Denver, Colorado area indicate values on the order of \$1,000 per acre-foot of transferable water depending on effluent water quality restrictions and operational policies.

Key words: Agricultural, Municipal, Supply, Operations Research.

70-006

Stevens, T.H., R.J. Kalter. Forecasting Industrial Water Utilization in the Petroleum Refining Sector: An Overview. Water Resources Bulletin of the American Water Resources Association, Vol. 11, pp. 155-163, No. 1, February 1975.

Various factors affecting the utilization of water in the petroleum refining industry are investigated. Refining accounts for approximately 10 percent of the total national industrial intake of water. Several direct factors influencing the demand for water in petroleum refining are discussed, including the price of water, environmental quality legislation, and technological factors. Empirical estimates of the potential impact of policy alternatives are presented. The relationship of these factors to the degree of water recirculation is also presented. Alternative petroleum consumption forecasts and refinery location scenarios are then developed. By way of illustration, a series of alternative water utilization forecasts for the domestic petroleum refining sector are then developed and compared to those presented by others.

Key words: Industrial, Recycling, Social.

70-007

Soltani, G.R. Economic Analysis of Water-Saving Techniques in Iran. Water Resource Bulletin, American Water Resources Association, Vol. 12, No. 6, December 1976.

The possibility of increasing the water supply for irrigation through adoption of more efficient water-application techniques as an alternative to new irrigation projects was studied in an irrigated region of Iran. Excessive water application at the farm level ranks high among the causes of water shortages in the selected region. An empirical analysis of the effect of water-saving technology on the farm operator's net return was made choosing two farms in the region as a case study. The problems facing these farms are common to most farms throughout the country. The results of the budgeting analysis of the selected farms indicated that an improvement in irrigation technique can result in the expansion of water supply and higher marginal value product for water. Comparing the costs of irrigation systems with the net returns resulting from the higher efficiency showed that such an investment is economically feasible.

Key words: Agricultural, Economics, Planning.

70-008

Palacios, E.V., J.C. Day. A New Approach for Estimating Irrigation Conveyance Losses and Their Economic Evaluation. Water Resources Bulletin of the American Water Resources Association, Vol. 13, No. 4, pp. 709-719, August 1977.

In this paper a new methodology for estimating conveyance efficiency within irrigation systems is presented. Based on statistical analysis of daily water releases from the source of supply and deliveries to the farmers in an irrigation district in Mexico, a linear model is obtained for estimating conveyance effi-

ciency and two component factors. One of these factors points out the relative importance of the operational losses (i.e., losses due to water management), and the second shows the importance of the fixed losses which can be attributed to the average flow through the canal network variations. An analysis of the expected benefits and costs accruing from system improvement permits derivation of a decision rule which may be used for analyzing the economic feasibility of lining in-place canals.

Key Words: Agricultural, Economics, Linear Programming.

70-009

Flinn, J.C. The Demand for Irrigation Water in an Intensive Irrigation Area. Australian Journal of Agricultural Economics, Vol. 13, No. 2, pp. 128-143, December 1969.

Linear programming procedures offer a useful means of estimating irrigation water demand functions at the farm level. If such estimates are to be aggregated to form regional demand schedules, care must be taken in the selection of representative farms if aggregation error is to be minimized. Both seasonal and intraseasonal demand schedules are presented since both are important when irrigation demand estimates are being developed. The results of a case study in Australia are shown.

Key Words: Agricultural, Linear Programming, Irrigation.

70-010

Yaron, D., E. Bresler. A Model for the Economic Evaluation of Water Quality in Irrigation. Australian Journal of Agricultural Economics, Vol. 14, No. 1, pp. 53-62, June 1970.

A model for determination of the efficient combination of water quantity and quality (salinity) in irrigation is presented. The efficient combination is evaluated with respect to a predetermined threshold salt concentration in the soil solution. A leaching model, designed for tracing salt distribution in the soil profile, serves as the basis for the analysis. The optimal quantity-quality combinations are derived with the aid of a linear programming model. An illustrative application of the model concludes the presentation.

Key Words: Economics, Agricultural, Irrigation, Quality.

70-011

Flinn, J.C., W.F. Musgrave. Development and Analysis of Input-Output Relation for Irrigation Water. Australian Journal of Agricultural Economics, Vol. 11, No. 1, pp. 1-19, June 1976.

Recent developments in climatology mean that economists now have a highly acceptable physical theory which can underlie their analysis of the economic aspects of water as an input to the production process, as a source of production instability, and as a major component of error in their estimated crop production functions. This paper presents a model and a procedure for synthesizing and analysing irrigation water crop input-output relations based on this theory. The importance of time of application of

water as well as quantity is shown. Different frequencies of irrigation are optimal at different times of the growing season.

Key words: Agricultural, Irrigation, Economics.

70-012

Mitchell, B., P.H. Leighton. A Comparison of Multivariate and Trend Forecasting Estimates with Actual Water Use. Water Resources Bulletin, American Water Resources Association, Vol. 13, No. 4, August 1977.

This paper describes a multivariate water forecasting procedure that is neither complicated, time-consuming nor expensive to operationalize. The forecasting procedure has been used to estimate the water demand for a proposed subdivision in Barrie, Ontario. Reliability is checked by applying the procedure to two existing subdivisions. Both the multivariate and trend forecasting procedures provide encouragingly accurate results when compared to actual use. While the multivariate procedure allows more precision, both procedures should be useful in forecasting water demand for smaller municipalities.

Key words: Statistics, Municipal.

70-013

Windsor, J.S., V.T. Chow. Model for Farm Irrigation in Humid Areas. Journal of Irrigation and Drainage Divn, Proc. Am. Soc. Civ. Eng., Vol. 97, No. IR3, pp. 369-385, September 1971.

A multicrop, multisoil farm irrigation system is broken down into a number of discrete units, and then analyzed by means of a two-level optimization approach. At the first level of optimization dynamic programming is used to determine, on a per acre basis, the optimal irrigation policy, the maximum expected profit, and the expected monthly irrigation labor and water requirements for each crop-soil combination and each level of irrigation development. At the next level of optimization linear programming is used to determine the irrigation system, the level of irrigation development, and the crop mix, which maximizes the expected farm profit without violating any of the farm resource limitations. The model assumes that water supply is the important variable which controls plant growth, and uses a production function which is based on the concept of stress days. To show how the procedure may be set up on a computer, a hypothetical two-crop, two-soil, farm irrigation system is analyzed considering several resource combinations.

Key words: Agricultural, Irrigation, Operations Research, Linear Programming.

70-014

Löff, G.O.G., A.V. Kneese. The Economics of Water Utilization in the Beet Sugar Industry. Resources For The Future Inc., (RFF, 1968), Washington D.C., 1968.

Analysis of water utilization and residuals generation in the production of sugar from sugar beets. Covers factors affecting water intake and BOD and suspended solids generation and the costs of reducing these discharges to different degrees. Study based on 100% sample of beet sugar plants in the United States. Analysis indicated that in-plant changes cost substantially less than treatment plants other than simple sedimentation.

Key words: Industrial, Economics, Quality.

70-015

Cootner, P.H., G.O.G. Löf. Water Demand for Steam Electric Generation: An Economic Projection Model. Resources For The Future Inc., (RFF, 1965), Washington D.C., 1965.

Analysis of the economics of water utilization in fossil-fueled power plants, primarily with respect to cooling water. Indicates the factors which determine cooling water demand and the response of demand to changes in in-take water price, and in constraints on discharges of heat to water courses.

Key words: Industrial, Recycling, Economics.

80-001

Kaila, J., J. Ranta, R. Rummukainen, P. Yletyinen. Systems Analysis of Sewerage Systems. YVY-publication 13, Helsinki, 1976.

The basic philosophy, goals and structure of sewerage systems models is presented for comprehensive planning and operation. In addition, a comprehensive simulation model for different types of waste water treatment plants is formulated, then programmed and tested.

Key words: Municipal, Computer Program, Sewage, Operations Research.

80-002

Yletyinen, P., M. Melaen, J. Kaila. Finnish Storm Water Management Modeling. A Finnish Report to IIASA concerning modeling of water demands and waste water discharges, 1977.

The SWMM model of the U.S. EPA has been modified in Finland. The modified version, the SIMU model, includes original blocks of SWMM, and also a new treatment plant block. The runoff and transport block have been verified against data from three combined sewer areas. Results of using the treatment plant block are presented. Experiences resulting from usage of the model in the practical design of waste water systems is presented. A description of further development is also given.

Key words: Municipal, Computer Program, Operations Research, Sewage.

80-003

Kim, J., M. Cuen. The Impact of Demand Modification (I & II). Journal American Waterworks Association, Vol. 69, No. 2, pp. 92-95, Feb. 1977.

Demand modification, a program that encourages reduced water consumption, seems to be the most feasible alternative to reducing the present trend of spiraling increases in water demand. Demand modification offers an opportunity to reduce both residential and commercial water demand by more than 30 percent. These changes in demand may occur at the critical price, the flat rate price, or the price at the minimum quantity demanded. Such changes must be considered in water demand forecasting and in assessing the impact of demand-modification programs.

Key words: Municipal, Industrial, Pricing.

80-004

Phillips, J., C. Kershaw. Domestic Metering - An Engineering and Economic Appraisal. Journal of the Institution of Water Engineers, Vol. 30, No. 4, pp. 203-216, June 1976.

The paper sets out the results of a six year investigation. The object of the investigation was to establish the true cost and the engineering aspects of universal metering and to compare the effect of charging for water supplied on a metered basis in Malvern, the only town in the United Kingdom with universally metered supplies, with Worcester, an adjacent town with a similar climate, whose consumers were charged for domestic supplies on a rateable basis and where only trade and industrial consumer were charged on a metered basis.

Key words: Municipal, Economics, Planning, Operations Research.

80-005

Bailey, J. water-flow Reduction from Households. Water and Sewage works, Reference Number, pp. R57-R74, April 1975.

As the population increases and the water supplies become more critical, it may be prudent to decrease the amount of water used in essential tasks. This probable need for change necessitates an examination of the different household water uses and the problems associated with changing any of the common practices or the appliances associated with the present water uses.

Key words: Municipal, Data, Planning.

80-007

Morgan, D. Residential Water Demand: The Case From Micro Data. Water Resources Research, Vol. 9, No. 4, pp. 1065-1067, Aug. 1973.

A cross section demand function for water is estimated using individual residential dwelling units as the sample. Both assessed value of property and number of persons per dwelling are significant determinates of the quantity of water demanded consistent with the theoretical development. Moreover, it is concluded that there are economies of scale of water use with respect to household size.

Key words: Municipal, Data, Economics.

80-008

Primeaux, W., K. Hollman. Factors Affecting Residential Water Consumption: The Managerial Viewpoint. Water and Sewage Works, Reference Number, pp. R138-R144, April 1974.

In water systems management and planning, people are confronted with the problem of providing a sufficient water supply without excess plant capacity. One important step necessary for providing this capacity is to isolate the variables which affect water consumption so that future requirements may be determined. The purpose of this study was to calculate through the use of multiple regression analysis, the effect that price and other selected economic and socio-economic variables have on the quantity of water demanded in residential households in northern Mississippi (USA). A regression equation using economic, socio-economic and climatic factors was derived to describe water demand.

Key Words: Municipal, Social, Economics, Pricing, Climate.

80-010

McCuen, R., R. Sutherland, J. Kim. Forecasting Urban Water Use: Commercial Establishments. Journal American Waterworks Association, Vol. 67, No. 5, pp 239-243, May 1975.

The establishment of water-quality standards and the imposition of moratoriums on new sewerline hookups have created a demand for methods of forecasting commercial water use, the research for which has been limited up to this time. Presented here, however, is a study which includes water-use prediction equations that may be helpful to urban design engineers and planners.

Key words: Municipal, Industrial, Planning, Data.

80-011

Mitchell, J., K. Kukuk. Metered Water versus Flat Rate System. Water and Sewage Works, Vol 123, No. 2, pp. 68-69, Feb. 1976.

Demand, load factors, fire use, peak rates of use and seasonal use all enter into the decision of whether you meter your water distribution system or whether you use a flat rate system. The article gives essential information that can be used to formulate a decision of this subject.

Key Words: Municipal, Planning.

80-012

Greenburg, M., R. Hordon. A Test of Alternatives for Meeting Public Potable Water Requirements. Water Resources Bulletin, Vol 12, No. 4, pp. 669-680, Aug. 1976.

The relative economic costs of meeting projected public potable water demands through increasing the supply, controlling the demand and increasing the capacity for interagency water transfers are explored. These alternatives and combinations are evaluated with the aid of a linear programming model in north-

eastern New Jersey, a major metropolitan region of over 4,500,000 people in the U.S.A., for the years 1975 to 2000. After more than 30 model tests it was found that a combination of increased interagency transfers and added water supplies was a least expensive solution.

Key words: Municipal, Statistics, Linear Programming, Economics.

80-013

Yamauchi, H., W. Huang. Organization and Statistical Analysis of water-consumption data at the Local Level. Journal of the American Waterworks Association, Vol. 69, No. 1, pp. 35-38, February 1977.

A better understanding of the empirical nature of water demand has become an important prerequisite for further improvements in planning and management of urban water resources. The development and analysis of data are explored with emphasis on computer analysis through multiple regression techniques.

Key words: Municipal, Statistics, Data.

80-014

Demard, H., D. Mascole. Demande en eau: cas des residences unifamiliales (Water Demand in One-family Dwellings). Technique et sciences municipale, December, 1973.

Design and optimization of water supply systems by computers call for knowledge of system pressures and flow rates. Water demand has been recorded for each one of nine one-family dwellings to ascertain rate and duration of uses and peak demand. Daily peak demand varies from 2.83 for one dwelling to 1.55 for 6 dwellings. Hourly peak demand varies similarly from 6.0 to 2.7.

Key words: Municipal, Computer Program, Operations Research.

80-015

Clark, R., H. Goddard. Cost and Quality of Water Supply. Journal of the American waterworks Association, January, 1977.

The relationship between water price and the factors which influence it is examined, as well as the elasticity of consumer demand. Regression techniques are utilized to perform a cross-section analysis, based on data collected as part of the EPA's Community Water Supply Survey.

Key words: General, Regional, Data, Economics, Statistics.

80-016

van Ufford, J.Q. Besparing van proceswater (Demand for recycling process water). in the Dutch Journal of (water) H2O, January, 1968.

Problems of industrial water supply and waste water disposal lead to segregation of waste water from uncontaminated cooling water, followed by economizations and reuse. Examples taken from various branches of industry illustrate this principle.

Key words: Industrial, Economics, Recycling.

80-017

de Rooy, J. Price Responsiveness of the Industrial Demand for Water. *Water Resources Research*, Vol. 10, No. 3, pp. 403-406, June 1974.

In order to determine the sensitivity of the industrial demand for water to changes in price a simple set of demand equations were formulated and tested with data on water use by 30 large plants. Results suggest that firms do adjust quantities demanded in response to even small price changes. Demand is also significantly affected by changes in output by technological improvements and by employment.

Key words: Industrial, Economics, Statistics.

80-018

Craddock, W.J. Irrigation Demand. The Allocative Conflicts in Water Resources Management, Agassiz Centre for Water Studies, University of Manitoba, Winnipeg, 1974.

The author describes the general characteristics of several alternative types of linear programming models and then outlines the results from several models which have been developed at the University of Manitoba for estimating irrigation demand.

Key words: Agricultural, Linear Programming.

80-019

Whittington, D. Forecasting Industrial Water Use, A Survey of the State of the Art. *International Institute for Applied Systems Analysis, Research Memorandum (forthcoming)*, February 1978.

This paper provides an introduction to the theory and analytical methods of forecasting industrial water use. Two basic approaches to the problem are presented - forecasting with and without the use of demand functions for water. Section 2 discusses the widely used water use coefficient method and regression techniques for forecasting water use. Section 3 reviews the statistical and economic-engineering models for deriving industrial water demand functions. Section 4 illustrates how water demand functions can be utilized in forecasting exercises and discusses the difficulties of forecasting industrial water use.

Key words: Industrial, Economics, General, Statistics.

80-020

Sewell, W.R.D., L. Rouech. The Potential Impact of Peak Load Pricing on Urban Water Demands: Victoria, B.C., a Case Study. *Priorities in Water Management*, edited by F.M. Leversedge, *Western Geographical Series*, Vol. 8, University of Victoria, B.C., pp. 141-161, 1974

The study reported here tested the conclusions of previous pricing studies in a particular geographical context and attempts to refine the theory relating to demand analysis. The authors focussed upon peak-load pricing and demand elasticities in a study of water consumption in Victoria, B.C. Their results contradicted previous research and a priori predictions concerning peak-load demand elasticities; a result they explain by the influence of block-rate pricing and the 'green-lawn syndrome'.

Key words: Municipal, Economics, Pricing.

80-021

Gouevsky, I.V., D.R. Maidment. Agricultural Water Demands: Preliminary Results of Silistra Case Study. International Institute for Applied Systems Analysis, RM-77-44, September 1977.

Preliminary results of the Silistra water for Irrigation Model (SWIM) for determining agricultural water demands in the Silistral region of Bulgaria are presented. For various areas of irrigated and non-irrigated land, and various volumes of water supply, SWIM uses linear programming to select the optimal combination of crop areas and production inputs so as to maximize annual net benefits from crop production in excess of target production quantities of each crop. Both normal and dry weather conditions are examined. The region's import-export balance is investigated for areas of irrigated land between 10,000 and 50,000 hectares and it is shown that total costs of crop production are minimized when the region is just self-sufficient in crop production. By means of demand curves it is demonstrated that the marginal values of land and water for irrigation are greater than their unit costs of development so that it is optimal to develop irrigation to the maximum area considered by the model.

Key words: Agricultural, Regional, Economics, Computer Program.

80-022

Kindler, J...Editor Proceedings of a Workshop on Modelling of Water Demands, 17-21 January 1977. International Institute for Applied Systems Analysis, Collaborative Publication (CP 78-016), July 1978.

In the years of 1976 and 1977 The International Institute for Applied Systems Analysis (IIASA) initiated a concentrated research effort focusing on modelling and forecasting water demands. A workshop on Modelling of Water Demands held at IIASA from 17-21 January 1977 was host to 29 people concerned with this topic from 14 different countries. The proceedings open with an introduction which attempts to provide the reader with the overall framework of IIASA's studies on modelling and forecasting of water demands. Then follows a collection of invited papers and national review reports which provide a good overview as to what is understood by "water demand analysis" in most of the National Member Organizations of IIASA.

Key words: General, Operations Research.

80-023

Sewell, W.R.D., B.T. Bower. Forecasting the Demands for Water. Policy and Planning Branch, Department of Energy, Mines and Resources, Ottawa, Canada, 1968.

This monograph contains the outcome of a Symposium on Methodologies for Forecasting Water Demands, sponsored by the University of Victoria and held in Vancouver on Dec. 11-12, 1967. Chapter 2 provides an introduction to the subject by setting out some broad guidelines for water demand forecasting and discusses some of the major difficulties encountered in preparing water demand forecasts. Chapters 3-7 outline methodologies relating to particular water uses - municipal, industrial, agricultural, water-based recreation, and various in-stream uses. Each chapter is supplemented with one or two critiques. Chapter 8 discusses the applicability of the various methodologies described in the volume to the Canadian scene, notes data requirements and points out certain research needs.

Key words: General, Municipal, Industrial, Agricultural, Quality.

80-024

McDonald, D.G., D.R. Maidment. The Pulp and Paper Industry and its water Use, A Summary. International Institute for Applied Systems Analysis, working Paper (internal publication) WP-77-15, 1977.

This paper summarizes the pulp and paper industry and this industry's dependence upon enormous quantities of water. The summary is in three parts and covers (i) the size and importance of the pulp and paper industry with selected data; (ii) an overview of the production processes involved in the manufacture of pulp and paper, this includes the various inputs and outputs associated with this industry; and (iii) covers the pollutants and the water pollution associated with this industry.

Key words: Industrial, Operations Research, Quality.

80-025

Tate, D.M. Water Use and Demand Forecasting in Canada: A Review. International Institute for Applied Systems Analysis, RM 78-016,

This paper reviews the state-of-the-art with regard to water use and demand forecasting in Canada, and presents a framework for such studies in a national, regional, and river basin context. The paper outlines the constituents of an adequate water demand forecasting program, including an alternative futures framework, a systems approach, water pricing, technological change and economic interrelationships. Canadian efforts in water demand forecasting are then reviewed, the finding being generally that most studies have used the simplistic coefficients approach. Exceptions have occurred in the few studies done at Canadian universities, mainly on residential water use, which use much more adequate methodologies than the coefficients approach. The

paper concludes by presenting a framework being developed in Canada for water demand forecasting at both the national and local (river basin) levels.

Key Words: General, national, Planning.

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Critical Evaluation of the Impact of Purported Improved Water Management Technology on Water Use Efficiency in Hissar District (Haryana). M.C. Agarwal, R.P. Agarwal, R. Singh. Proceedings of the Second IWRA World Congress on Water Resources, "Water for Human Needs", New Delhi, India, Vol. 1, pp 209-214, 16 Dec. 1975.

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Evaluation on Returns from Irrigation of Corn in a Sub-Humid Climate. V.N. Asopa, J.W.B. Guise, E.R. Swanson. Agricultural Meteorology, Vol. 11, pp. 65-78, November 1973.

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