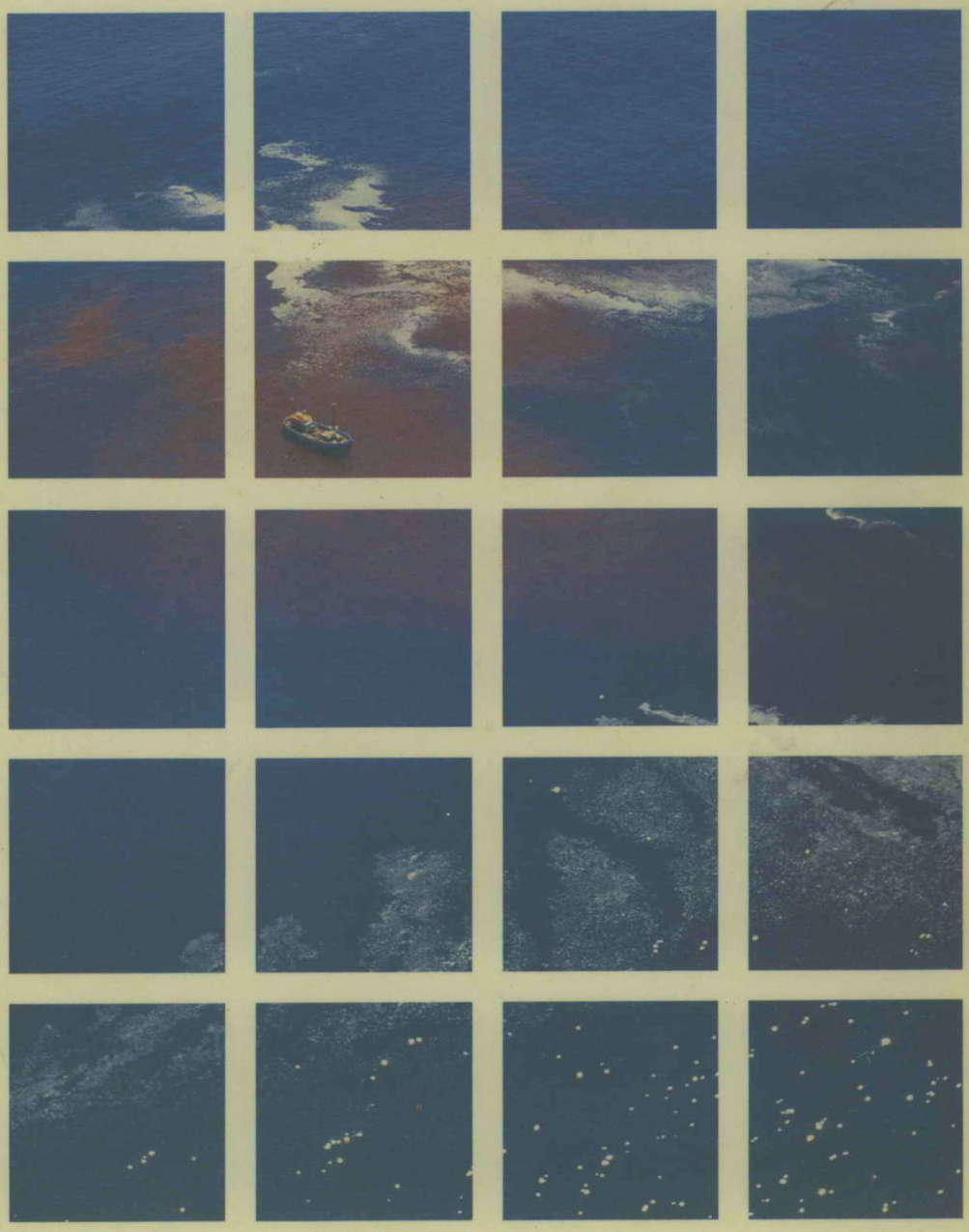
1988 ANNUAL REPORT



Water Research Commission

1988 ANNUAL REPORT

An aerial photograph of the survey vessel sampling the rhodamine coloured surfaced effluent plume from the Camps Bay sea outfall sewer (Photograph courtesy of C Best of EMA / CSIR).

Water Research Commission

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ISBN 0 947447 14 8

Hierdie verslag is ook in Afrikaans beskikbaar

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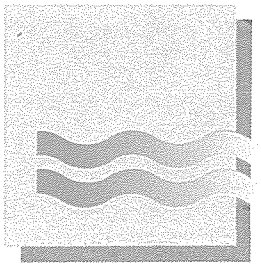


The objectives of the Water Research Commission

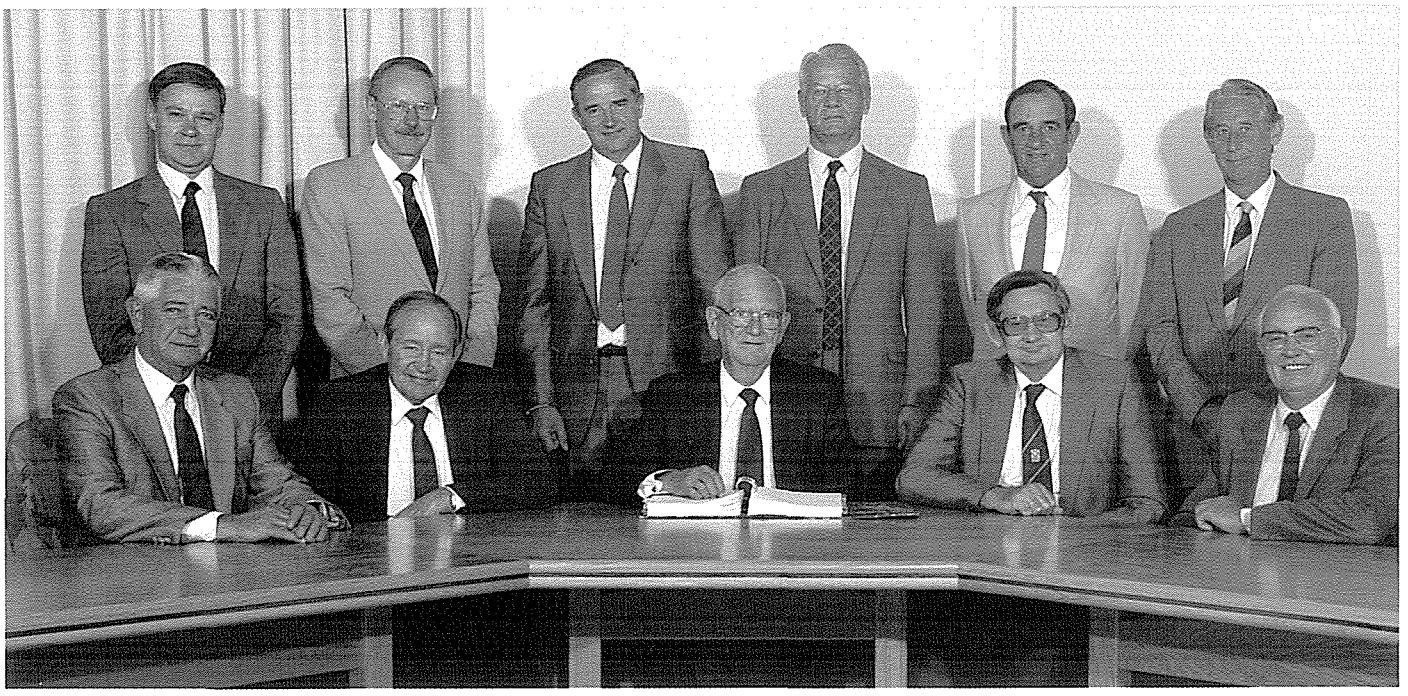
In terms of section 2(3) of the Water Research Act 1971 (Act No 34 of 1971) the objectives of the Commission are "to coordinate, to promote, to encourage or to cause to be undertaken, as determined by the Minister specifically or in broad outline, research in respect of

(a) the occurrence, preservation, conservation, utilization, control, supply, distribution, purification, pollution or reclamation of water supplies and water;

(b) the use of water for
(i) agricultural purposes;
(ii) industrial purposes; or
(iii) urban purposes".

Section 3(1) of the above-mentioned Act describes the functions of the Commission and stipulates *inter alia* that the Commission shall "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

Members of the Water Research Commission as on 31 December 1988



Back row (from left):
Mr PE Odendaal, Executive Director. **Mr M Erasmus,** Co-opted member. Deputy Director General: Department of Water Affairs. **Dr CF Garbers,** President: CSIR. **Dr N Stutterheim** (OMS), Co-opted member. Chairman: Board of the University of the Witwatersrand; and Chairman: Telephone Manufacturers of SA. **Mr AJ Raubenheimer** (DMS), Former Minister of Water Affairs. **Dr AJ Heyns,** Superintendent General: Department of Agriculture and Water Supply.

Front row (from left):
Prof DJ Schoeman, Former Dean: Faculty of Engineering, University of Pretoria. **Dr WL van Wyk,** Former Deputy Director General: Department of Mineral and Energy Affairs. **Dr JP Kriel,** Chairman. Consultant: Special Water Studies; and former Secretary of the Department of Water Affairs. **Mr GCD Claassens,** Director General: Department of Water Affairs. **Mr JG du Plessis,** Former Director General: Department of Water Affairs. **Absent: Dr DW Immelman,** who was a member up to 10 May 1988.

Senior Personnel

PROFESSIONAL

DEPUTY EXECUTIVE DIRECTOR
Dr WHJ Hattingh

RESEARCH MANAGERS
Dr OO Hart (Industrial water)

Mr JE McGlashan (Municipal effluents and sludge; marine disposal of effluent)

Dr MJ Pieterse (Water quality studies; salinisation re mining activities; Editor *Water SA*)

Dr CF Schutte (Water treatment and reclamation; desalination; dry cooling)

DEPUTY EXECUTIVE DIRECTOR
Mr DS van der Merwe

RESEARCH MANAGERS
Mr HC Chapman (Urban hydrology and water supply)

Mr H Maaren (Surface hydrology and water resources)

Mr HM du Plessis (Salinisation; eutrophication)

Dr PCM Reid (Irrigation)

Dr GC Green (Rainfall stimulation; meteorological sciences)

ASSISTENT RESEARCH MANAGER
Mr AG Reynders (Ground water)

ADMINISTRATIVE

DIRECTOR: ADMINISTRATION
Mr HC Lombaard

DIRECTOR: FINANCE
Mr PM van der Schyff

Water Research Commission
PO Box 824
PRETORIA
0001
14 February 1989

Dear Mr Kotzé

We take pleasure in submitting to you, herewith, the report of the Water Research Commission for the period 1 January to 31 December 1988.

The balance sheet and statement of revenue and expenditure for the financial year to 31 December 1987, as certified by the Auditor General, as well as a receipts and payments account for the year ended 31 December 1988 and a budget for 1989, are furnished in Chapter 20 of this report.

Yours respectfully

JP Kriel
CHAIRMAN

PE Odendaal
EXECUTIVE DIRECTOR

Mr GJ Kotzé, MP
Minister of Environment Affairs and of Water Affairs
Private Bag X9039
CAPE TOWN
8000

1 The year under review

Water research covers a particularly extensive field as may be evidenced from the following list of research areas supported by the Water Research Commission (WRC):

- Surface hydrology
- Ground water
- Hydrometeorology
- Rainfall stimulation
- Irrigation
- Salinisation
- Eutrophication
- Sewage
- Sludge management
- Marine disposal of effluents
- Water quality and health aspects
- Urban water supply
- Water related socio-economic studies
- Industrial water

Because of the wide field it encompasses, water research is pre-eminently a multi-disciplinary activity and therefore the WRC funds research at a large number of organisations. In 1988 the WRC supported 115 projects in terms of research agreements, with the following organisational distribution:

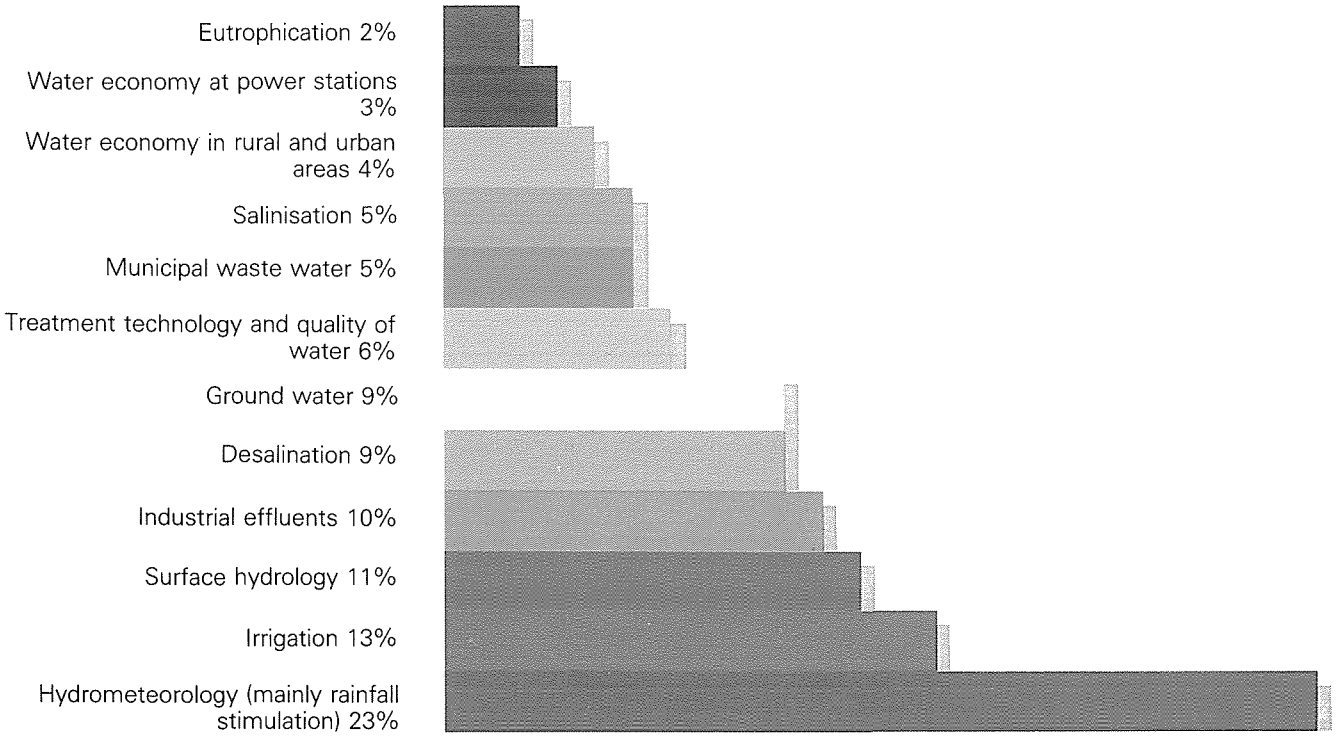
University departments	60
CSIR	38
Local authorities	9
Government departments	8
Private organisations	20
Other organisations	8
	143

The number of organisations exceeds the number of projects because occasionally more than one organisation is involved with a particular project.

In addition to the direct funding of research projects, the WRC also funds four research support services. These services are directed at increasing the productivity and efficiency of water research and at providing the water industry with easy access to research knowledge and different types of data. These services are the following:

- The SA Water Information Centre
- The Hydrological Information System
- The Computing Centre for Water Research
- A Ground-water Data Base.

Allocation of funds (%) to various research areas during 1988.



MASTER PLAN FOR RESEARCH ON SURFACE HYDROLOGY

The WRC accords a high priority to research on surface hydrology and therefore took the necessary measures to draw up a master plan which comprises research needs and priorities. This plan was published in 1988 entitled *Surface Water Resources of South Africa: Research Needs*.

The document was drawn up in cooperation with the country's foremost hydrologists and by employing the Analytic Hierarchy Process. It is envisaged that the master plan will be refined and updated progressively.

The plan is not only meant to guide the WRC's own funding of research on surface hydrology, but also that of other organisations in the country which undertake research in this field. In this manner the master plan also serves as a coordinating tool.

HYDROLOGICAL DESIGN GUIDES

The devastating floods of 1987/1988 during which, *inter alia,* the walls of hundreds of farm dams burst, once again focused the attention on the need for up-to-date design flood criteria for hydraulic structures. Therefore the completion of a set of hydrological design guides by the University of Natal in 1988 was particularly timely and met a long-felt need by engineers and hydrologists.

The guides, which were presented to the Chairman of the WRC in 1988 by the Vice-principal of the University, Prof C de B Webb, represent the culmination of ten years of research. The research was carried out by the University's Department of Agricultural Engineering, supported financially by the WRC.

In order to promote technology transfer, the compilers of the guides conducted a country-wide series of workshops. These

The devastating floods of 1987/88 once again focused the attention on the need for up-to-date design flood criteria for hydraulic structures.

took place in Cape Town, Port Elizabeth, Pietermaritzburg, Bloemfontein, Pretoria and Pietersburg. The workshops were well-attended by consulting engineers and representatives of various government departments, universities and local authorities.

BIOLOGICAL PHOSPHATE REMOVAL

The phosphate content of treated effluents is the principal cause of water enrichment (eutrophication) which leads to undesirable algal blooms in rivers and impoundments in particular. For this reason a phosphate standard of 1 mg/ℓ as P was promulgated in terms of the Water Act for effluents in certain catchments.

Two important projects on the biological removal of phosphates from effluents terminated in 1988. The projects were carried out by the University of Cape Town's Department of Civil Engineering and the Municipality of Johannesburg. The two projects were carried out in close interaction with each other, the laboratory work being undertaken by the University and the full-scale experiment by the Municipality.

Important progress was made and the results were disseminated at a one-day symposium held in Johannesburg. The symposium generated considerable interest and was attended by, *inter alia,* representatives from Zimbabwe and Swaziland.

COMPOSTING OF SEWAGE SLUDGE BY FORCED AERATION

The treatment and disposal of sludge which is produced during the treatment of sewage continues to be a major problem for local authorities.

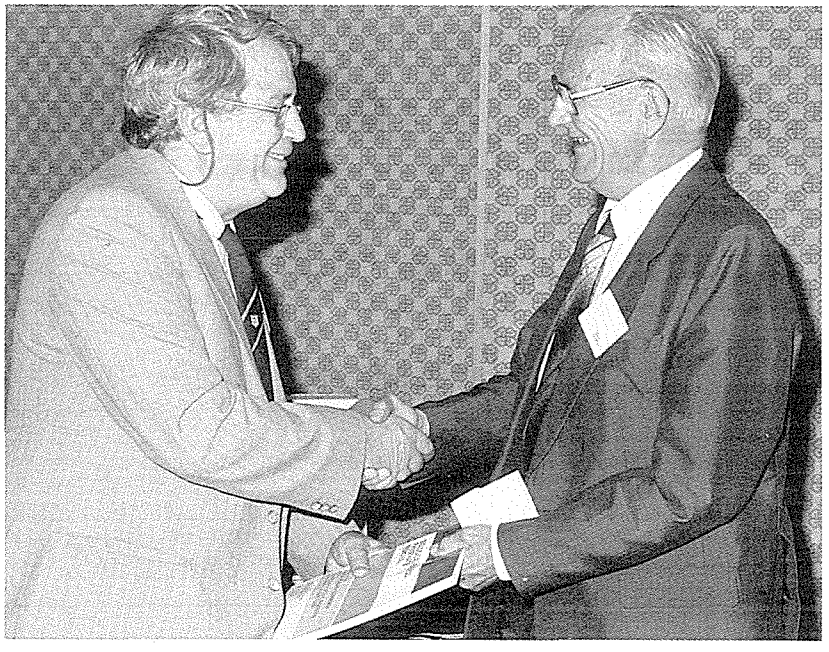
The CSIR's Division of Water Technology earlier conducted an investigation, on behalf of the WRC, into the application of forced aeration for the stabilisation, disinfection and composting of sewage sludge. The project was successfully completed at pilot scale and the process produces a usable and safe compost. The process was subsequently publicised by means of seminars and publications.

In 1988 the technology found full-scale application at the Municipality of Stellenbosch's sewage works. The Stellenbosch plant will also serve as a demonstration plant at which other local authorities and consultants can observe the full-scale operation of the process.

MARINE DISPOSAL OF EFFLUENTS

The disposal of effluents to sea requires a thorough evaluation of the environmental and engineering implications. In view of this and of the increasing concentration of population and industries at the coast, the WRC contracted the CSIR's Division of Earth, Marine and Atmospheric Science and Technology (EMA) to draw up guidelines for the marine disposal of effluents through pipelines.

In support of this brief, EMA conducted several experiments at sea to test the validity of theoretical predictions for the initial dilution of effluents discharged to sea through pipelines. These predictions play a vital role in the design of pipelines.



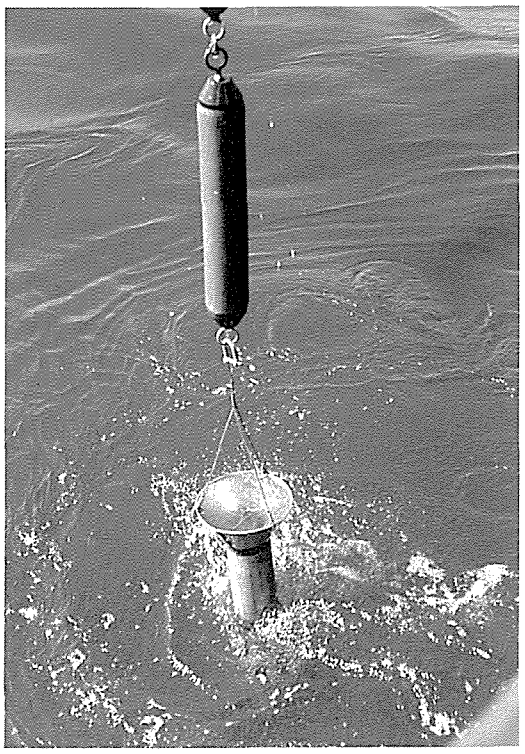
Prof G v R Marais (University of Cape Town) handing over the final report entitled "Biological Excess Phosphate Removal" to Dr JP Kriel (WRC) during a technology transfer symposium in Johannesburg.

Three experiments were conducted on the existing pipeline in Camps Bay, as well as a further experiment in Hout Bay. The conclusion arrived at was that the actual dilution was indeed far greater than the theoretically predicted values.

TREATMENT OF TEXTILE EFFLUENTS

In 1988 the WRC published guidelines for the management of effluents in the textile industry. The publication is based on research done by the Pollution Research Group of the University of Natal's Department of Chemical Engineering. The guidelines pertain specifically to effluents originating in the textile industry's dyeing and printing processes, and emphasise measures for water recycling. In this type of effluent colour had always been a problem in water reuse and had considerably increased the costs of tertiary treatment.

The research team did not concern themselves with standard approaches, but concentrated on modern technology such as membrane processes. Of special value for the industry is the fact that several case studies are included in the publication.



Sampling for pollution in the marine environment.

WASTE-WATER TREATMENT IN THE FISHING INDUSTRY

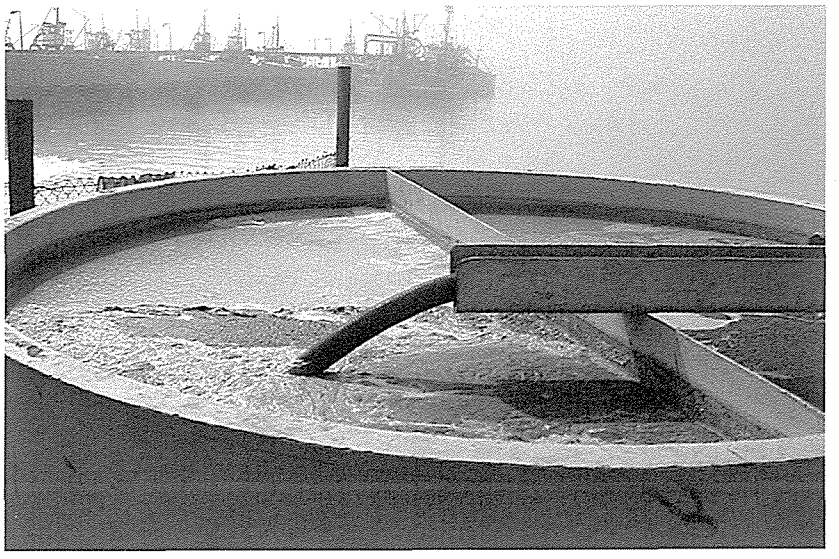
In 1987 the WRC published guidelines on the management of waste water in the fishing industry. By way of a follow-up, a seminar was held in 1988 at Laaiplek on the West Coast to relay the relevant information to the fishing industry in a more personal manner.

The project leaders responsible for the research and for drawing up the guidelines elucidated the salient points of the guidelines for representatives of all the fish factories in South Africa, as well as of South-West Africa/Namibia. It was clear from the reaction of those present that such seminars present valuable opportunities to promote the application of research results.

WATER AND EFFLUENT MANAGEMENT IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

The fruit and vegetable processing industry, established in various regions of the country, uses large quantities of water, es-

Waste-water treatment in the fishing industry.



pecially for washing purposes, because of the nature of the product. It also produces highly polluted organic effluents.

The WRC contracted a firm of consulting engineers to conduct a country-wide investigation into water and effluent management in the industry and to prepare guidelines in this regard which were published during the year.

Target water consumption and waste generation figures are presented in the guidelines. Factors are also indicated which promote excessive water consumption and waste generation; techniques are described to conserve water and to control pollution; and methods are proposed for the pretreatment of effluents and the reclamation of by-products.

The survey was carried out and the guidelines drawn up in close cooperation with the South African Fruit and Vegetable Canning Association.

PROGRESS IN IRRIGATION RESEARCH

In view of the good progress made in irrigation research over the past few years, the WRC's Coordinating Committee for Irrigation Research made two important recommendations during the year. Firstly, that an irrigation manual should be compiled, consolidating the progress made. The country's foremost irrigation researchers will contribute to the manual. Secondly, it was recommended that a national irrigation symposium be held, probably in 1990. Such a symposium has now become expedient in view of the considerable progress made since the previous national symposium held in 1967.

OVERSEAS CONSULTANT ON IRRIGATION RESEARCH

One of the USA's foremost researchers in the field of soil/plant/water relationships visited South Africa during the year as consultant to the WRC. He is Prof RJ Hanks of the Utah State University in Logan — Department of Soil Science and Biometeorology. Prof Hanks's directive was to evaluate critically the progress made in various WRC projects and to advise on modelling approaches for irrigation research.

AID TO UPGRADE IRRIGATION MANAGEMENT

The results of a research project which had been carried out by the Department of Soil Science of the University of the Orange Free State were disseminated to agriculturists and farmers by means of a number of one-day courses. With knowledge of certain basic soil properties, rooting patterns of crops in the relevant soil, the typical potential transpiration rates, together with the project findings, the plant available water capacity of the soil profile can be predicted, water extraction patterns can be described and the inception of plant water stress can be identified. In this way optimal management of the soil as a water reservoir in irrigation practice can be promoted. Leading farmers are already successfully applying this approach.

COMPUTER PROGRAM FOR THE DESIGN OF IRRIGATION SYSTEMS

At the request of the WRC, a firm of consulting engineers developed a computer program package for the design of irrigation systems. The package is known as the IDES irrigation design program. The firm is currently compiling a manual for use with the package. In addition, a series of six introductory courses on the program were presented in the major centres throughout the RSA. The purpose of this exercise was to introduce the research and results to irrigation farmers. Government and semi-government institutions, universities, consulting engineers and agricultural cooperatives, amongst others, were involved. In addition to systematising the design procedure of sprinkler and micro-irrigation systems, the computer program has the unique feature that it provides aids for evaluating different designs with regard to optimal water application. The introductory courses were aimed at demonstrating the merit of the evaluation techniques, as well as their application, in order to ensure an optimal irrigation system.

COMPUTER PROGRAM FOR THE SOFTENING AND STABILISATION OF WATER

Unstable water can be aggressive or scale forming. This can lead to a deterioration in water quality (for example the solution of metals such as lead, cadmium, copper, zinc and iron), turbidity, tastes and odours, loss of pipe capacity, pressure losses, leakages, replacement of pumps and increased maintenance costs.

For this reason the WRC initiated research on the softening and stabilisation of water at the University of Cape Town's Department of Civil Engineering. The development of a user-friendly computer program entitled STASOFT and developed in terms of this research, has made a significant contribution in the field of water treatment. The program is already being used country-wide by chemists, engineers and operators, in the management of water treatment plants.

At the request of certain large industries, the University is already adapting the program for water with high concentrations of dissolved salts.

WORKSHOPS ON WATER TREATMENT AND DESALINATION

Two similar workshops, one on water treatment and the other on desalination, were arranged by the WRC during the year. The sessions focused on new technological developments and research progress, as well as on problem areas requiring further research.

Attendance was limited in order to ensure lively discussion. Through this approach, good interaction was achieved in both cases between representatives of the industry and of the research community. Viewpoints which emerged are being followed up by the WRC.

HIGHLIGHTS IN RESPECT OF EUTROPHICATION RESEARCH

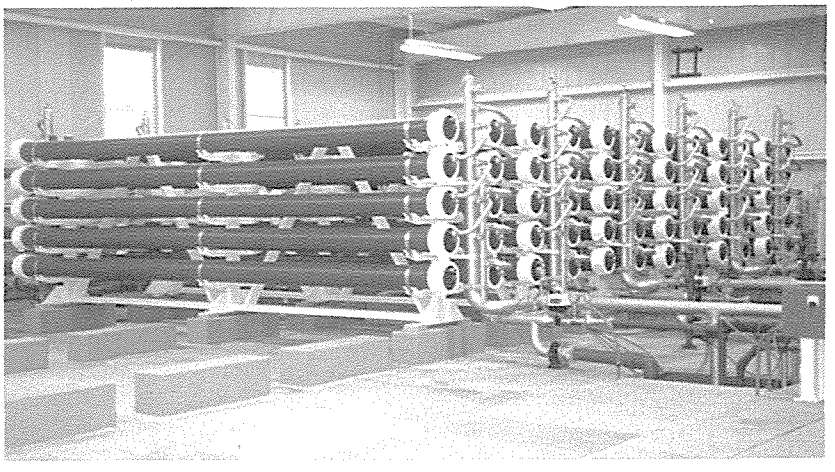
The WRC has been supporting research on the enrichment of the water environment with plant nutrients (eutrophication) and the concomitant prolific algal growth and other water quality problems since shortly after its establishment.

When it became clear that a reduction in the concentration of phosphates in effluents would be the most effective way of controlling eutrophication, the Department of Water Affairs implemented a 1 mg/ℓ P standard for effluents in certain sensitive areas in 1985. The WRC currently supports the development of a user-friendly decision support system by the Division of Water Technology of the CSIR, in which the existing models and knowledge regarding the components and processes which contribute to eutrophication and algal growth are to be integrated. This will enable the managers of water quality to predict how the typical phosphate and algal concentrations in dams will be affected by alternative management options and by the P limits being considered for a catchment.

Although not completely finalised, this decision support system has been used by the Department of Water Affairs during the past year to reconsider the effect of current eutrophication control measures in sensitive catchments, and to evaluate the effect which a relaxation or tightening of these measures would have.

WRC PUBLICATION SELLS WELL OVERSEAS

In 1985 the WRC published a manual which is selling well overseas. The manual



A reverse osmosis plant for the desalination of waste water.

was written for the WRC by consultants and deals with the causes and control of sludge bulking and scum formation in the activated sludge process for sewage treatment. Sludge bulking is the phenomenon where sludge in the secondary settling tank of the activated sludge process with poor settling properties does not settle and results in carry-over of sludge in varying quantities in the final effluent. This has a deleterious effect on the performance of the process and on the quality of the effluent.

An agreement has been reached with a publisher in the USA to market the manual overseas. Sales are proceeding beyond expectations.

PRIVATISATION

With the principle of privatisation being strongly advocated in South Africa at present, the decision by the WRC in its choice of direction in the execution of its statutory duties taken shortly after its inception in 1971 has again been shown to have been the correct one. It was decided at the time that the WRC would not establish research facilities itself, but as far as practically possible, would utilise existing facilities and expertise by having research carried out under contract.

Prof Colin Webb (right), Vice-principal of the University of Natal, handing over the hydrological design manuals to Dr JP Kriel (left), Chairman of the WRC.

By adapting this approach, the WRC not only eliminated unnecessary duplication of research facilities, but could concentrate objectively on its coordinating and funding role, unfettered by vested interests. By adhering to this policy the WRC managed to mobilise expertise over a wide front of disciplines and organisations in the interests of water research in South Africa.

FUNDING OF RESEARCH AT UNIVERSITIES

In 1988 the WRC financially supported 60 projects at 36 different university departments.

An added advantage of the WRC's financial support of water research at universities is that it results in expert training to the benefit of the country's water industry. In this regard it should be mentioned that at the University of Natal's Department of Agricultural Engineering 23 master's degrees and 4 doctorates have already been attained, or are now registered, through WRC projects.

In the case of the University of Cape Town's Department of Civil Engineering (Chair for Water Resources and Public Health Engineering), the situation is even more impressive; namely 32 master's degrees and 9 doctorates, the greatest number of higher degrees yet awarded under any professor at this University.

Centres of expertise such as the two mentioned, established with WRC financial support, have already drawn several overseas students as well as overseas professors who have spent their sabbaticals there. This is in addition to the students who are sent there for further training by operational organisations such as state departments and consultants.

These centres play an important role in technology transfer by incorporating research results in curricula and by acting as consultants.

WATER SA

The multi-disciplinary scientific journal *Water SA* was launched in 1975, with the

purpose of creating a medium for the publication of research results by water scientists and engineers. By making use of referees a high standard is maintained and the journal enjoys international status. This is evident from the feedback in the form of letters and comments from all over the world.

An encouraging aspect of *Water SA* is the good support it receives from South African authors, as well as the willing cooperation of competent referees.

Subscriptions presently stand at 2 500 of which about 1 000 are from overseas. *Water SA* is also covered by more than twenty international abstracting services.

THE COMPUTING CENTRE FOR WATER RESEARCH

The Computing Centre for Water Research (CCWR) is two years old now and has made remarkable progress. The centre is already in a position to render a unique service which assists in bridging the geographic distance separating researchers, by sharing information, data and computer programs.

The CCWR was established by the company ISM, the WRC and the University of Natal on the campus of the University in Pietermaritzburg. The main objective of the centre is to provide water researchers with computing facilities — currently at no cost to the researchers.

The CCWR currently has 78 registered users in Pietermaritzburg, Cape Town, Grahamstown, Bloemfontein, Johannesburg and Pretoria. The centre is linked to various national computer networks and is accessible from any point in the country.

The centre's facilities are used in a wide field of water research, such as projects in connection with satellite observation, irrigation needs, flood estimates, water quality, and water and effluent purification. The results of this research are made known to consultants and planners through the centre, which helps to shorten the period between research and application.

WRC MOVES TO NEW BUILDING

Since its establishment in 1971 the offices of the WRC have been in the Van der Stel building in the city centre of Pretoria, distributed over the fifth and seventh floors. The WRC's gradual expansion and the growing need for increased storage space to cope with the increased production of publications, necessitated new accommodation. It was established that the purchase of a building would effect cost savings in the long term and a building was therefore purchased in Rietfontein, Pretoria. Before the purchase, the building was evaluated by the Department of Public Works and Land Affairs on behalf of the WRC and the valuation was considerably higher than the purchase price. The WRC moved into the building on 1 October 1988.

The building has business rights for which the space is already being let. The WRC also does not occupy all of the office space and arrangements have been made for the partitioning and letting of the unoccupied space.

2 Hydrometeorology

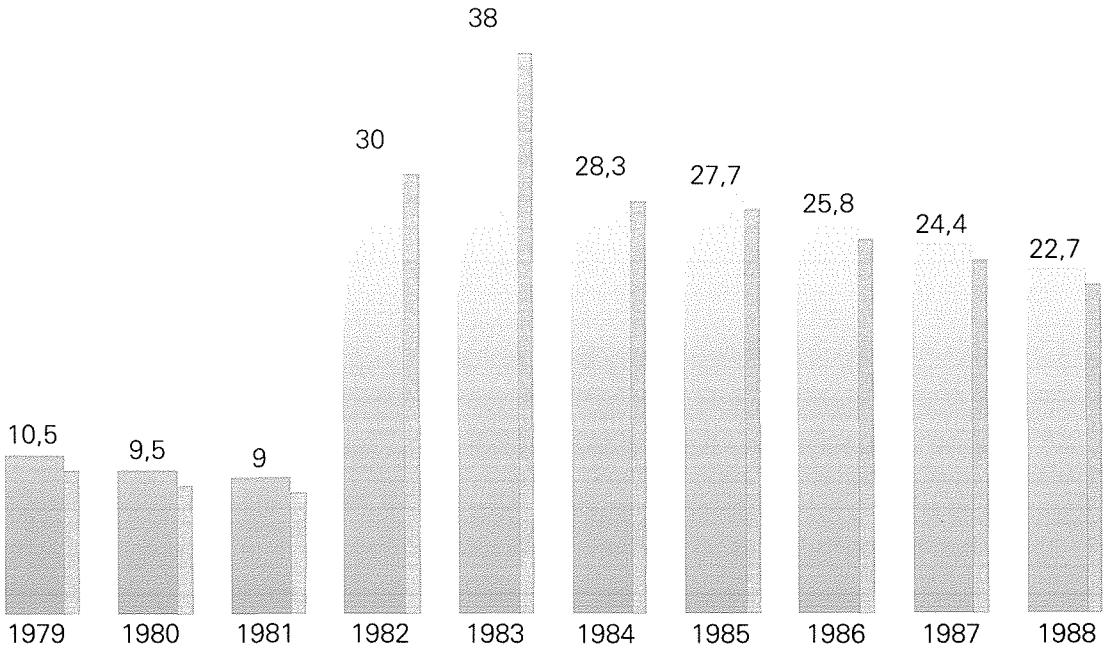
The atmosphere is the immediate source of South Africa's water supply while the sun and the atmosphere together provide the energy which drives the hydrological cycle. The overwhelming importance of solar and atmospheric influences on the amount and variability of the national water supply makes it imperative for the Commission to maintain a definite involvement in research to acquire an adequate understanding of these and related influences, so that water management procedures can be improved and the potential for augmentation assessed.

PRECIPITATION STATISTICS AND STOCHASTIC CLIMATE MODELS

Several significant advances have resulted from hydrometeorological research projects supported by the Commission. The recent major revision of South Africa's precipitation statistics, both from a spatial and temporal point of view, is already proving of great benefit to the study of water resources. Another achievement has been the development of a generalised daily rainfall model and the evaluation of localised parameters necessary to generate representative rainfall sequences long enough to provide useful inputs to a wide range of hydrological and agroclimatic models, and enable risks associated with rainfall variability to be assessed in any area of South Africa. Good progress in extending this daily rainfall modelling to the modelling of the simultaneous daily behaviour of several other hydrologically important climatological variables is being made by the Department of Mathematical Statistics at the University of Cape Town.

RAINFALL STIMULATION

The major part of the Commission's support for hydrometeorology has to date been focused on assessing the potential for rainfall stimulation through cloud seeding. This is a highly complex subject, which has been addressed over several years by major research projects in the Lowveld and escarpment areas of the eastern Transvaal near Nelspruit, and, in collaboration with the Weather Bureau, in the highveld areas surrounding Bethlehem in the Orange Free State. Convective clouds in these two areas have been extensively characterised. Important differences both in cloud characteristics and rain-forming mechanisms between the two areas have been established. In both areas there are indications that clouds satisfying certain established criteria respond consistently, from a statistical point of view, to experimental cloud seeding. While results are promising, it must however be em-



Funding of research on Hydrometeorology expressed as a percentage of total WRC research expenditure (1979 to 1988).

phasised that, due to the nature of the research, these cloud responses as observed by radar and through in-cloud sampling with aircraft, have not yet been linked to rainfall increases on the ground.

During 1988 the research team at Nelspruit extended their cloud observations to the area around Ermelo and Carolina in the highveld of the eastern Transvaal. This will enable similarities and differences in cloud characteristics, rain-forming mechanisms and seeding responses to be established with respect to the Nelspruit and Bethlehem environments. The movement of the one centre of research activity from Nelspruit to Carolina promises to have two major advantages. Firstly, the area is more representative of the region along the continental divide where, if proved effective, cloud seeding is most likely to be used in the future for runoff augmentation. Secondly, the terrain is much more suitable for establishing sought after relationships between radar-determined cloud properties and rainfall, both at cloud base and on the ground. The latter is an important step towards realising the major objective of quantifying the potential for rainfall enhancement.

A DISCUSSION OF NEW PROJECTS

Research on the reconstruction of the climatic history of the last 2 000 years in the summer rainfall regions of southern Africa.

Essential to the efficient long-term management of South Africa's water resources is a knowledge of the long-term variability in the rainfall and runoff. Projections of conditions which can be expected in the future are however hampered by the relatively short periods of 100 years or less, for which historic records are available. During the year the South African Museum in Cape Town commenced a three-year research project which will explore the possibility of extending climatic records several hundreds of years back into the past by making use of evidence provided through anatomical analysis of fossil and modern-day wood samples. The research will be carried out by first selecting five extant tree species, whose wood also commonly occurs as charcoal in the fossil record of the last 2 000 years in a number of summer rainfall regions. The influence of climate on the modern-day wood anatomy of these species will be quantified and used to infer climatic conditions under which the fossil wood was formed.

Research on precipitation and airflow in cumulus clouds

The CSIR has carried out radar observations of clouds and storm precipitation for many years and has gained considerable experience. It recently acquired a triple Doppler radar system which is a valuable tool for research into cloud growth and storm precipitation. In view of the substantial benefits such research will have for the future use of radar in water resources research and management, the Commission will be providing support for a research project on airflow and precipitation in cumulus clouds in terms of a three-year contract with the Division of Earth, Marine and Atmospheric Science and Technology (EMA). The main aim of the project will be to establish relationships between the spatial distribution of precipitation in clouds and on the ground and internal airflow in thunderstorms. An additional aim will be to make further contributions to the estimation of rainfall intensities from radar reflectivity data.

LIST OF RESEARCH PROJECTS

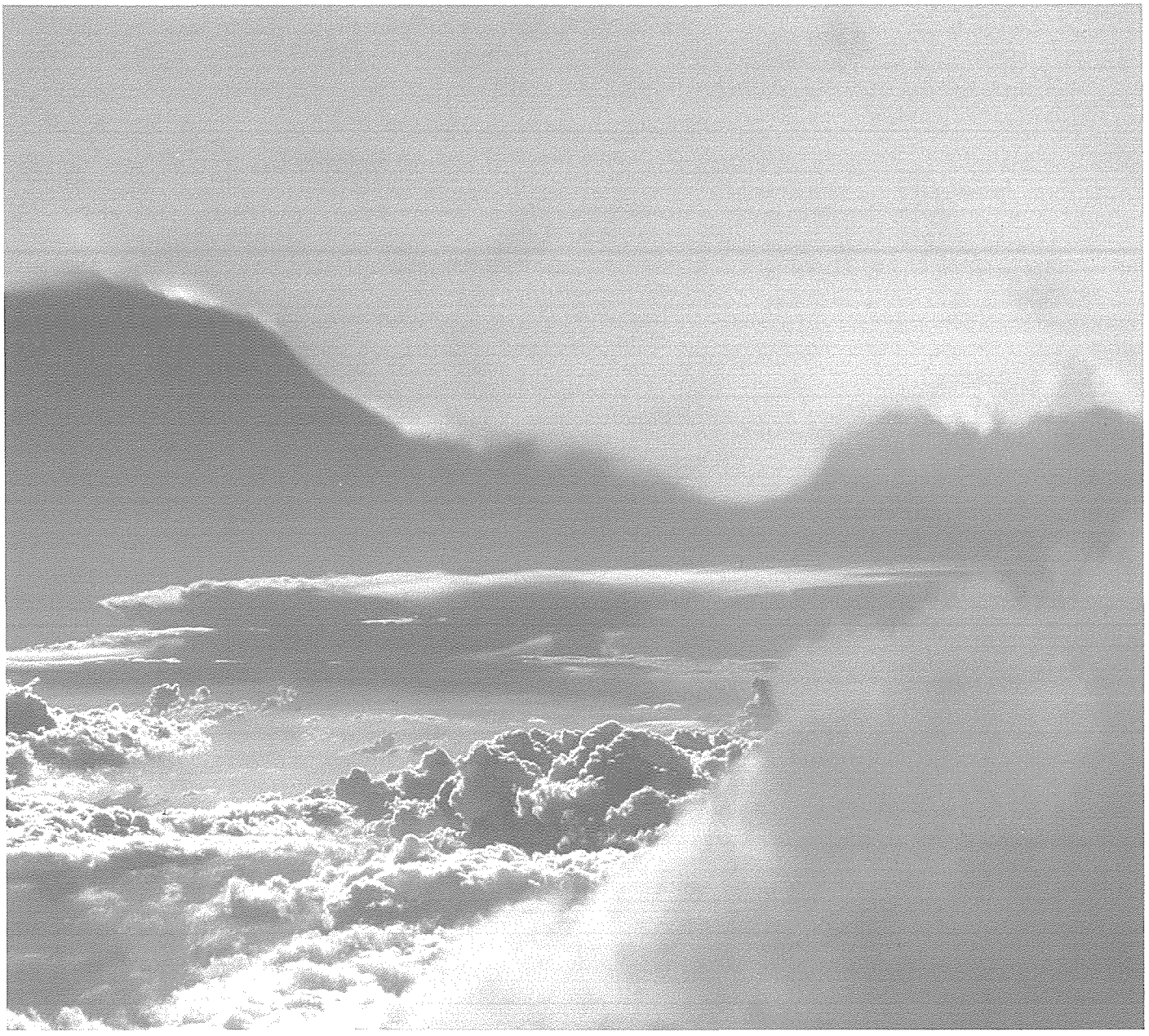
Current projects

- Bethlehem precipitation research project (The Department of Environment Affairs — Weather Bureau).
- Programme for atmospheric water supply at Nelspruit and Carolina (The Company for Research on Atmospheric Water Supply (CRAWS), subcontracting the Division of Earth, Marine and Atmospheric Science and Technology (EMA) of the CSIR and CloudQuest (Pty) Ltd).
- The development of a stochastic daily climate model for South African conditions (The University of Cape Town — Department of Mathematical Statistics).

New projects

- Research on the reconstruction of the climate history of the last 2 000 years in the summer rainfall region of southern Africa (The South African Museum).
- Research on precipitation and airflow in cumulus clouds (CSIR — Division of Earth, Marine and Atmospheric Science and Technology (EMA)).

Clouds associated with thunderstorms are the focus of attention.



3 Surface hydrology

Since surface hydrology deals with water occurring on and/or near the land surface and therefore includes streamflow, impounded water, catchment processes and soil moisture, research on surface hydrology is important in view of its contribution towards alleviating the constraints in South Africa's water management. Supply and demand interactions between the water utilisation cycle and the hydrological cycle form part of this broad definition of surface hydrology. The overall goal of research into surface hydrology is to aid the optimum development and management of the surface water resources of southern Africa.

In order to achieve this overall goal, the primary goals of the research are the following:

- accurate assessment of the temporal and spatial characteristics of surface water resources;
- development of the scientific means of evaluating alternative water resource management options.

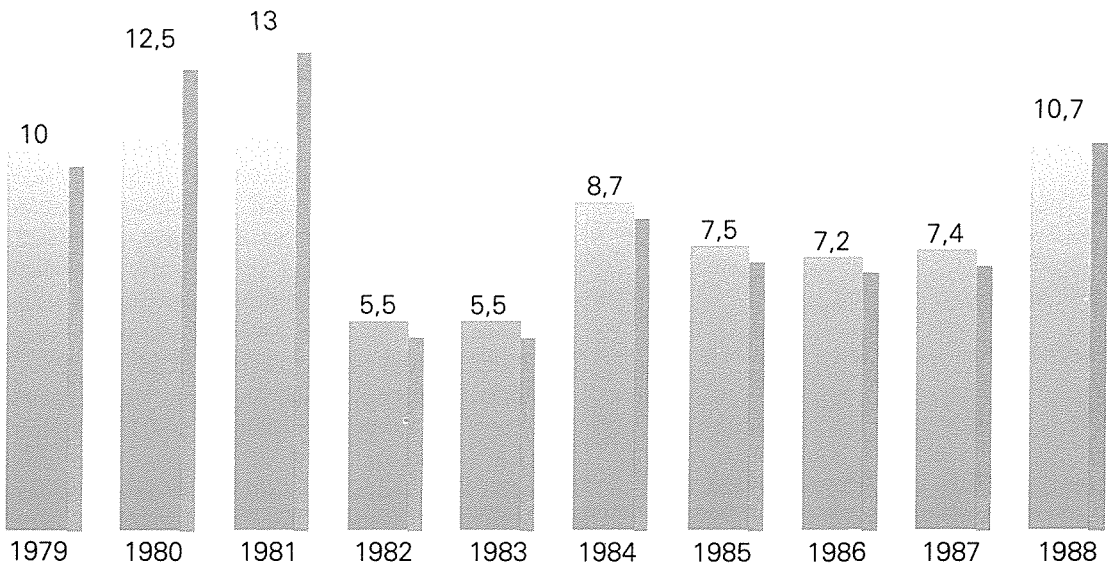
Fundamental to all water resources research and planning activities, however, is a knowledge of the actual present availability of water and its utilisation. For this reason the collection and processing of reliable data with reference to the hydrological cycle are accorded a high priority. The WRC's involvement in the improvement of hydrological information systems is reported on in **Chapter 18**.

During the year the WRC sponsored eight research projects on surface hydrology, of which one was completed and four new projects were started.

SURFACE WATER RESOURCES OF SOUTH AFRICA: RESEARCH NEEDS

A document with the above-mentioned title was prepared by the WRC in collaboration with the Department of Water Affairs and the Department of Environment Affairs. In effect it is a **master plan** for hydrological research which describes the present needs and priorities at this point in time. In time this plan will be integrated with those for other areas of water research funded by the WRC.

All relevant research and funding organisations are encouraged to use this document to guide their decisions in the interests of effective coordination. Resource allocations made with this document in mind will enhance the coordination of water research in South Africa, which is a statutory responsibility of the WRC. The information from this plan, comprising research activities, goals, objectives and priorities has been entered into a computerised data base and will be revised and updated regularly.



Funding of research on Surface Hydrology expressed as a percentage of total WRC research expenditure (1979 to 1988).

REPORT ON A COMPLETED PROJECT

Hydrological research in catchments of the eastern and southern Cape

This project was carried out by Rhodes University between 1983 and 1988, following on previous projects initiated in the Ecca catchments of the semi-arid eastern Cape. The emphasis was on the testing of stochastic and regression type models as well as on the testing of conceptual single-event hydrological models.

Multiple regression modelling of storm-flow discharges proved to be a useful hydrological tool but no clearly defined trends were found to suggest that the magnitude of regression coefficients was directly related to easily recognised catchment characteristics.

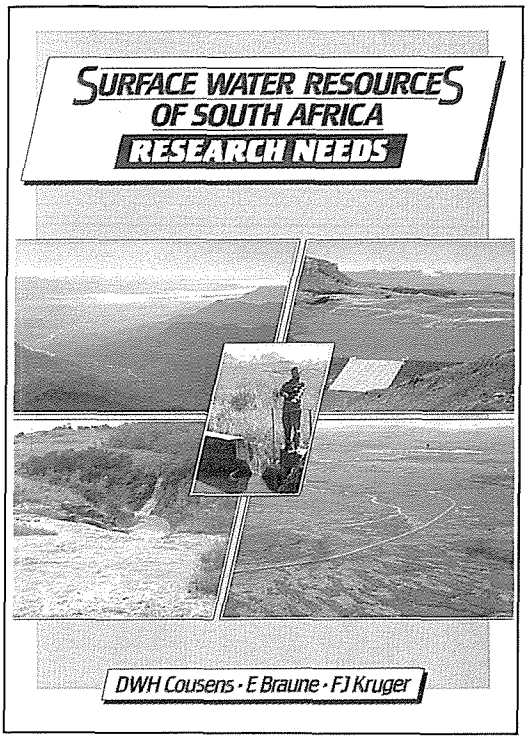
It was found that the period of monthly flow records was too short to develop satisfactory autoregressive moving average (ARMA) type models. For monthly rainfall in semi-arid and sub-humid regions it was concluded that data over 40 to 50 years are required for such models to stabilise.

As part of a separate project observations are continuing at some of the catchments not affected by the construction of a dam on the Ecca River.

Four deterministic single event storm runoff models were tested in the southern Cape catchments and on a selection of medium sized catchments (5 to 150 km^2) throughout the Republic (30 catchments in 10 regions). The following conclusions were drawn:

- The variable runoff proportion model performs better for multi-peaked events and the semi-distributed version of the models performs better when the rainfall input is more spatially variable.
- A rainfall time interval of 15 min proved satisfactory in the South African catchments tested.
- The more complex, variable runoff proportion model (as distinct from the constant runoff proportion models) is expected to perform better in ungauged situations because parameters are more closely related to physical catchment characteristics.

In general the conclusion was reached that in future development of hydrological modelling, a balance must be reached between the level of understanding of processes and the uncertainties related to the quality of input data needed.



A publication entitled "Surface Water Resources of South Africa: Research Needs" was published during the year.

A DISCUSSION OF NEW PROJECTS

The investigation of the hydrological response to third world settlements in the peri-urban areas of Natal/Kwazulu

This new three-year project is being undertaken by the University of Zululand. Extensive peri-urban areas surrounding the large metropolitan areas in South Africa are experiencing rapidly increasing population density. These settlements are affecting the environment for example, through denudation and degradation of the vegetation. The changes will in turn affect the hydrological response and could lead to increased pollution of the water resources in such areas. There is a need to determine the influence of these settlements on the hydrology and to develop appropriate management strategies for their control.

The aims of the project are:

- to identify temporal changes in the hydrological response which may be the result of the changes in land use;
- to quantify the differences in the hydrological response of disturbed and undisturbed areas;
- to characterise the suspended and dissolved solids in relation to discharge from the disturbed and undisturbed areas; and
- to adapt existing models so that it is possible to model adequately the responses of the disturbed and undisturbed areas.

The development of a systems model for the Mgeni catchment

This three-year research project was initiated during the year in terms of an agreement between the WRC and the University of Natal. The major water supply systems to the large metropolitan areas are becoming more and more complex as they are being developed and as demands for water increase. As with the Vaal River system, for which a major simulation study is currently being undertaken by the Department of Water Affairs with the aid of a consulting engineering group, there is a need to be able to simulate the Mgeni River system. To undertake such a simulation, from both a quality and quantity point of view, an appropriate model must be developed.

The University of Natal has been developing a hydrological model which is suitable for adapting and applying to the Mgeni system. The objective of this project is therefore to adapt the existing model for use on the Mgeni catchment. The work will entail developing a semi-distributed, cell type rainfall/runoff model which is sensitive to changes in land use.

Hydrological modelling studies in the eastern Cape

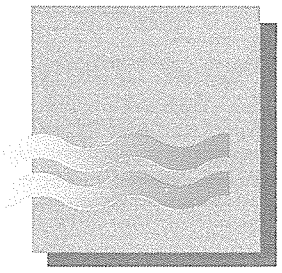
The construction of a dam in the Ecca River for the supply of water to the Lower Fish River Irrigation Scheme and Grahamstown have affected some of the gauging sites for the Ecca research area. To continue the hydrological research on semi-arid catchments it was necessary to establish an additional area for observations which is being done in the catchment of the Coerney River, a tributary of the Sundays River. These catchments were specifically chosen to provide data which are typical of semi-arid areas of South Africa. The first objective of this new project which is being executed by Rhodes University over a 5-year period is the establishment of the new research catchments, and the quantification of the physical characteristics of the area.

In view of the desirability of shifting the emphasis of hydrological research to the development of management aids more firmly based on the physical laws governing water movement in soils, plants and the atmosphere, the second aim of this project is to investigate methods of improving the hydrological models by moving towards more physically-based approaches, but without neglecting the later application needs of such models.

The third aim is to improve the model drainage components, especially from the root zone to the deeper subsurface regions of the soil. In this regard the emphasis will be on monitoring and then modelling lateral and vertical moisture fluxes at or near the base of the root zone.

Development of a model to simulate flow in alluvial rivers

A computer model which can simulate unsteady, non-uniform flow in alluvial rivers will help to determine the effects of floods and water resources development on the regime of rivers and on sediment transport by such rivers. This new project which is being undertaken by a consulting engineering firm over a period of three and a half years, envisages developing and validating such a model using an efficient numerical method to solve the differential continuity equation for water and sediment discharge and the dynamic equation for the discharge of water. The model will be of a general nature although site specific information will need to be used to implement it for any particular application.



LIST OF RESEARCH PROJECTS

Completed projects

- Hydrological research in catchments of the eastern and southern Cape (Rhodes University — Department of Geography).

Current projects

- Applied hydrological process and modelling studies for the determination of water and sediment yield (The University of Natal — Department of Agricultural Engineering).
- Research on the effects of urbanisation on catchment water balance (The University of the Witwatersrand — Department of Civil Engineering, Water Systems Research Programme).
- Development of methods to assess the impact of agricultural practices on water resources in southern Africa (The University of Natal — Department of Agricultural Engineering).

New projects

- The investigation of the hydrological response to third world settlements in the peri-urban areas of Natal/Kwazulu (The University of Zululand — Department of Hydrology).
- The development of a systems model for the Mgeni catchment (The University of Natal — Department of Agricultural Engineering).
- Hydrological modelling studies in the eastern Cape (Rhodes University — Department of Geography).
- Development of a model to simulate flow in alluvial rivers (A firm of consulting engineers: Bruinette, Kruger and Stoffberg Inc.).

4 Ground water

Ground water, in the hydrological cycle, can be defined as that water which has infiltrated past the root zone and moved into the zone of saturation. South Africa is, in general, not well endowed with ground water. In over 80% of the area of South Africa ground water can be abstracted only from secondary aquifers which are mainly of a localised nature, occurring in joints and fractures. It is only from the dolomitic aquifers, primary coastal aquifers, and large-scale fracture zones that substantial volumes of ground water can be abstracted for any length of time. Water quality in the arid and semi-arid areas of the country is often poor, compounding the problem of limited quantity. The potential ground-water yield for South Africa is estimated to be 16% of the potential surface water yield. However, the fact that across South Africa, 105 towns use ground-water resources exclusively, while a further 15 towns use both surface and ground water, underscores the importance of this valuable resource for two thirds of our country.

As our knowledge of the occurrence of ground water in South Africa increases, aspects such as management and protection of the ground-water resources begin to play an increasingly significant role. In determining research priorities, the Coordinating Committee for Geohydrological Research (CCGR) is revising and updating the existing research master plan. Factors such as ground-water contamination and management are to be addressed in greater detail. A ground-water project register is being compiled which will assist in coordinating the research effort countrywide.

During 1988 the Commission supported nine ground-water research projects, of which three commenced during the year, four are current and two were completed.

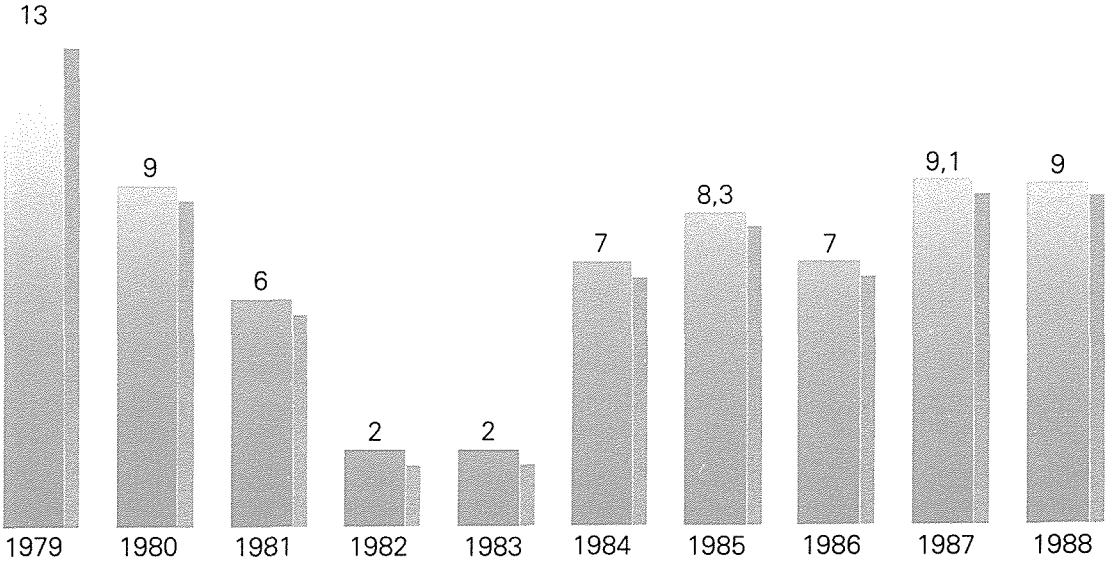
A REPORT ON COMPLETED PROJECTS

An investigation into rainfall recharge to ground water

The long-term controlled use of ground water depends on the amount of water recharging the aquifer system. Consequently a reliable evaluation of the rainfall recharge to ground water would aid the prediction of long-term yields of aquifers and the exploitation of ground-water resources.

The primary objective of the investigation was to gain an understanding of the recharge process and to establish better estimates for ground-water recharge from rainfall through improved methodology and numerical modelling.

A model, ACRUWAT, has been developed to simulate potential recharge. The model provides a physically based means of estimating the amount of water leaving the root zone at a specific site. A methodology for estimating recharge by means of a geostatistical package has also been devised. Progress has been made towards a



Funding of research on Ground Water expressed as a percentage of total WRC research expenditure (1979 to 1988).

further understanding of recharge in southern Africa by the completion of this research project, but much research is still required.

The development of a National Ground-water Data Bank

One of the basic requirements for ground-water research programmes as well as routine short-term ground-water investigations is access to all of the available information that is relevant to the study. Knowledge of what information is already available and where to find it, considerably improves our ability to find a viable ground-water supply, to evaluate the extent of the aquifer and to assess the potential yield of the resource.

With this in mind the Institute for Ground-water Studies (IGS) developed a National Data Bank facility for ground-water data. The data base is housed at the Directorate of Geohydrology of the Department of Water Affairs. For the use of the data base, the IGS has developed software which facilitates the processing of geohydrological and geohydrochemical data.

The Ground-water Data Bank has been completed and is available for use by geohydrologists, as well as by various other professionals, working in the field of ground-water development, supply and research. Certain short-comings were, however, perceived and this has led to research on the enhancement of the National Ground-water Data Base facilities.

A DISCUSSION OF NEW PROJECTS

Research on the enhancement of the National Ground-water Data Base facilities

In view of the rapid developments in computer hardware and the associated software boom, the present data base facilities will soon be inadequate and outdated. It is essential that the time and money spent to achieve the high level of expertise should not go to waste by allowing computer and geohydrological technologies to surpass the sophistication provided for by the data base. Consequently, the Institute for Groundwater Studies (IGS) proposed a three-year project aimed at maintaining the data base; adapting software to suit the requirements of the end user; and propagating the use of the data base facilities through lectures, brochures and the presentation of papers.

A geohydrological investigation and evaluation of the Zululand coastal aquifer

This five-year project is being undertaken

Lake Sibayi forms part of the delicate ecosystem along the Zululand coastal plain.

by the CSIR in terms of an agreement with the Commission.

The main objectives of the project are:

- to investigate the nature, extent and geohydrological properties of the aquifer underlying the Zululand coastal plain from Richards Bay to the Mozambique border;
- to determine the vulnerability of the aquifer to ground-water contamination and the concomitant effect on the freshwater lake system; and
- to determine the exploitation potential of the coastal aquifer.

Research on the development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State gold fields

Little is known about the extent to which South Africa's ground-water resources are being polluted by various activities in the industrial, domestic and agricultural sectors. There is inadequate knowledge of the impact that mining activities are having on the quality of ground-water resources. Consequently there is a need to develop appropriate monitoring strategies to determine the past and potential future impacts on ground water; to develop relevant control procedures to minimise future impacts and to develop remedial procedures where possible.

With this in mind the Institute for Groundwater Studies proposed a three-year research project to develop techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State gold fields.

LIST OF RESEARCH PROJECTS

Completed projects

- An investigation into rainfall recharge to ground water (A firm of consulting engineers: Steffen, Robertson and Kirsten Inc.).
- The development of a National Data Bank for Ground-water Data (The University of the Orange Free State — Institute for Groundwater Studies; and the Department of Water Affairs).

Current projects

- Modelling of the ground-water quality in the Atlantis aquifer (The University of the Orange Free State — Institute for Groundwater Studies).
- Research on the exploitation potential of Karoo aquifers (The University of the Orange Free State — Institute for Groundwater Studies).
- Research on the use of electromagnetic exploration techniques for the development of ground-water resources (The University of Pretoria — Department of Geology).
- Evaluation and development of techniques for the estimation of geohydrological parameters by using geoelectrical methods (CSIR — Division of Earth, Marine and Atmospheric Science and Technology).

New projects

- Research on the enhancement of the National Ground-water Data Base facilities (The University of the Orange Free State — Institute for Groundwater Studies).
- A geohydrological investigation and evaluation of the Zululand coastal aquifer (CSIR — Division of Earth, Marine and Atmospheric Science and Technology).
- Research on the development of techniques for the evaluation and effective management of surface and groundwater contamination in the Orange Free State gold fields (The University of the Orange Free State — Institute for Groundwater Studies).

Electrical resistivity soundings are being undertaken by the CSIR to determine the thickness and extent of the Zululand coastal aquifer.

5 Irrigation

Since its inception the Commission has funded irrigation research in South Africa to the value of nearly R6 million. To date a large percentage of these research funds has been used for basic, or process-orientated, research. As indicated, however, in the *1987 WRC Annual Report,* a trend towards more practical, end-user orientated research has emerged. This indicates not only an awareness amongst researchers of the importance of introducing their work to the end users, but also of the increasing confidence the researchers have in their knowledge of irrigated agriculture. The current trend also indicates that end users, in this case the irrigation farmers, are becoming increasingly aware of the benefits to be derived from using scientifically sound irrigation practices.

During 1988 the Commission financed 21 irrigation research projects, four of which were completed during the year and six of which were new projects.

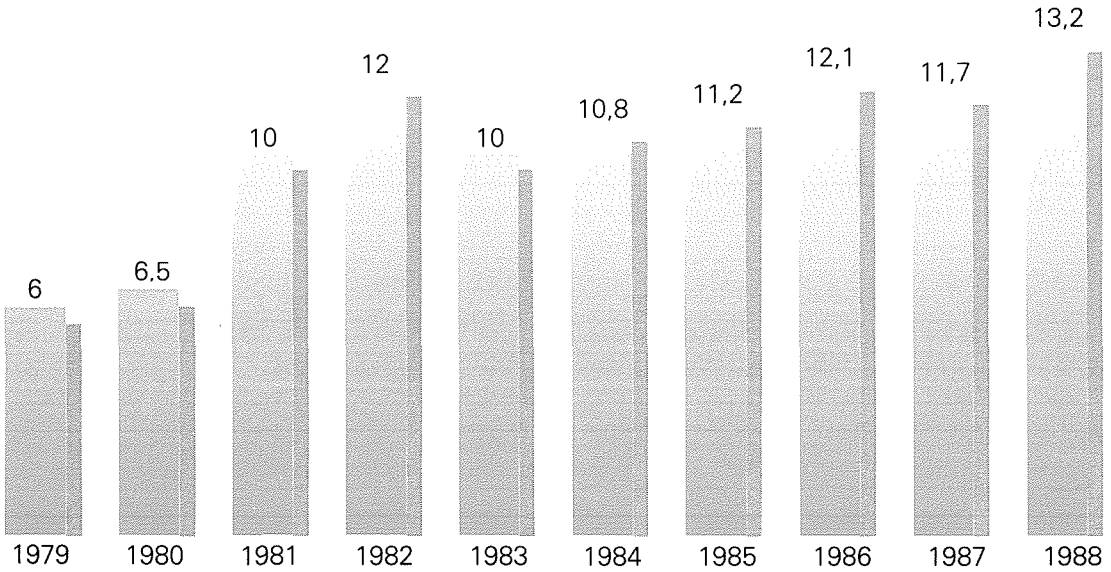
A REPORT ON COMPLETED PROJECTS

Research on the effect of different times and intensities of internal plant moisture stress on photosynthesis, respiration and water use efficiency of certain agronomic crops

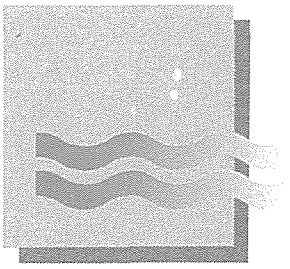
This project, which commenced in 1981, was completed at the end of 1987 by the University of the Orange Free State. The final report, entitled *Die Invloed van Verskillende Tye en Intensiteite van Plantwaterstremming op Fotosintese van sekere Akkerbougewasse* presents results of research on the physiological behaviour of maize, wheat, sunflower and cotton plants subjected to water stress at different stages in the growth cycle. Plant responses were monitored as water stress developed to predetermined levels of severity, and after subsequent relief by irrigation. The work was carried out mainly under glasshouse conditions, with the intention of perfecting measuring techniques to be used, and obtaining preliminary results to be confirmed, in subsequent full-scale field research on the Riet River irrigation scheme. Although severe drought prevented the commencement of the field research component during the project period, field research has now been initiated in terms of a follow-up project.

Research on the use of the soil/root conductance index and stress ratio as inputs for the determination of irrigation requirements of selected soil/plant/atmosphere systems

Research carried out by the University of the Orange Free State between 1984 and early 1988 has resulted in a final report entitled *'n Waterbalansmodel vir Besproeiing gebaseer op Profielwatervoorsieningstempo en Gewaswaterbehoeftes.* In a preceding project, the researchers had suc-



Funding of research on Irrigation expressed as a percentage of total WRC research expenditure (1979 to 1988).



ceeded in defining and quantifying the potential water supply rate to a crop root system throughout a soil profile as a function of a conductance index, depending on the soil water content and the root length density. Evaluation of the profile water supply rate constituted an important step towards identifying the onset of crop water stress. In this project, the potential water supply rate was evaluated during the growing season for a large number of crop/soil combinations on commercial irrigation farms in the Vaalharts, Sandvet and Ramah areas. The work succeeded in demonstrating the practical value of the profile water supply rate concept which will aid assessment of profile water holding capacities of soils and for the better planning of irrigation scheduling strategies.

A detailed regional soil moisture deficit analysis for irrigation planning in southern Africa

The final report on this project conducted between 1983 and 1988 by the University of Natal, is entitled *Crop Water Requirements, Deficits and Water Yield for Irrigation Planning in Southern Africa.* The project addressed the need to provide the irrigation planner with the means, firstly, of helping to decide on the need to irrigate a given crop in a specific environment and secondly, of assessing the irrigation requirements of the crop at various levels of risk. Clearly the large number of possible combinations of crop, soil and climate, peculiar to a planting location and date, made the potentially unmanageable bulk of a complete set of guidelines something to be avoided. Solutions were found to the problem of reducing bulk, while retaining the essential detailed information provided by a comprehensive analysis. Analyses were carried out for each of 712 homogeneous climate zones throughout southern Africa, especially delimitated for this purpose. This spatial detail and resolution constituted a considerable improvement, compared to that achieved in previous presentations of estimated irrigation requirements of crops in South Africa. The detailed results of this research will be disseminated through the Computing Centre for Water Research on computer compatible media.

An investigation into the condition of soils irrigated over a protracted period and an evaluation of applicable selection criteria, and reclamation and control measures

This project was carried out by the Potchefstroom University for CHE over the period 1983 to 1987. Owing to the distribution of soils in the area under investigation, a meaningful comparison of the extent to which different soils, which had been irrigated for different periods, had degenerated, was not successful. It was found, for instance, that certain soils on the flood plain which have been irrigated for almost 75 years, are not found in the higher lying areas. The latter have been irrigated for 20 years. Another aspect which was investigated is the influence of magnesium in the soil and water of the area on the chemical and physical condition of the soil. Several aspects concerning the influence of magnesium on *inter alia* clay mineralogy, ion exchange and the release of electrolytes were investigated intensively. The results of these investigations will contribute to a better understanding of the swelling and dispersive characteristics of soils. This will have a positive influence on irrigation management and efficiency.

A DISCUSSION OF NEW PROJECTS

Research on maximising irrigation project efficiency in different soil/climate/irrigation situations

Previous research had demonstrated the feasibility of providing an effective irrigation scheduling service to farmers. A serious limitation of this research was that the scheduling service ignored on-farm constraints such as availability of water and water distribution networks. This limitation will be overcome if this new 5-year project, undertaken by the University of the Orange Free State, succeeds in integrating irrigation scheduling models with water supply and distribution models at irrigation project level, as well as at farm level.

Research on the storage and utilisation of rain water in the soil for the stabilisation of plant production in semi-arid areas

Little quantitative research on dry-land soil moisture management has been done in the past. This 6-year research project, undertaken by the University of the Orange Free State, will study the effect of different soil cultivation and utilisation practices on the ground-water balance. The practices that result in the most effective storage and usage of rain water will be identified. Management guidelines for optimum utilisation of rain water in semi-arid regions will thus be provided.

Research on the factors affecting the water use efficiency of irrigated crops, with special reference to the physiological responses of these crops

Crop yield is, to a large extent, determined by the physiological behaviour of the plant with respect to water, nutritional and environmental conditions, during different growing stages. Furthermore, plant physiological reactions to water stress vary during the growing season. The new 5-year project, undertaken by the University of the Orange Free State, will concentrate on the field determination of plant physiological reactions, due to water stress, during the growing season. The optimum photosynthetic, transpiration and translocation reactions, for a given water supply, will be determined.

Research on the estimation and evaluation of moisture stress in crops by means of remote control aerial surveillance

Quantification of crop water stress, using crop canopy temperatures, has been proved successful. Canopy temperatures are usually measured by using either hand-held infrared thermometers or are derived from thermal line scanners, mounted in aircraft. The former yield the temperatures of a relatively small area and the latter are extremely expensive. This 5-year research project, undertaken by the University of the North, will attempt to perfect techniques of measuring large area crop canopy temperatures by using relatively inexpensive remote control surveillance aircraft.

Research on the water use efficiency of certain irrigated temperate pasture species

The implementation of the National Grazing Strategy and subsidy schemes will encourage farmers to replace cash crops and will most probably lead to increased production of pasturage under irrigation. To date the irrigation strategy for pasturage has been to achieve maximum yield and to prevent water stress totally. This approach is not necessarily appropriate from the point of view of economics and optimum water use. This project which is being undertaken by the University of Pretoria over five and a half years, aims at determining irrigation norms for annual and perennial forage crops, as well as concomitant optimum water use efficiencies.

Development of a manual for use with the IDES computer programs for the design of irrigation systems

During the period 1 July 1982 to 30 Sep-

Radiation instrumentation used in irrigation scheduling. The instruments are:
A Campbell-Stokes sunshine recorder;
A Kipp and Zarien solarimeter; and
A Net radiometer.
(Photo courtesy of Department of Water Affairs).

tember 1986 a firm of consulting engineers, supported financially by the Commission, completed this project titled *Research on the Development of Procedures for the Selection of Suitable Irrigation Methods and for the Design of Irrigation Systems*. This project's objective was to develop a comprehensive procedure for the selection and design of irrigation systems in order that the method of irrigation selected would be the most suitable in terms of the effective utilisation of water, energy and labour. The design procedure was also expected to take into account all the system properties in order to be as accurate as possible, as well as to contain certain evaluation criteria.

These aims were realised and made available in the form of computer programs which can be used for the design of sprinkler, drip or microjet irrigation systems. To promote the use of these programs, the Commission decided in consultation with the consulting engineers to commercialise them. Before embarking on a marketing action, the package first needs to be rounded off by developing a user manual which will enable judicious use of the programs. Being the developers of the program, the consulting firm is the obvious organisation to develop the manual. This firm will also present a number of introductory courses to bring the package and its capabilities to the attention of other consulting engineers, cooperatives etc. The whole development is therefore in essence a technology transfer action by means of which the results of a research project are to be rounded off and introduced to potential users.

LIST OF RESEARCH PROJECTS

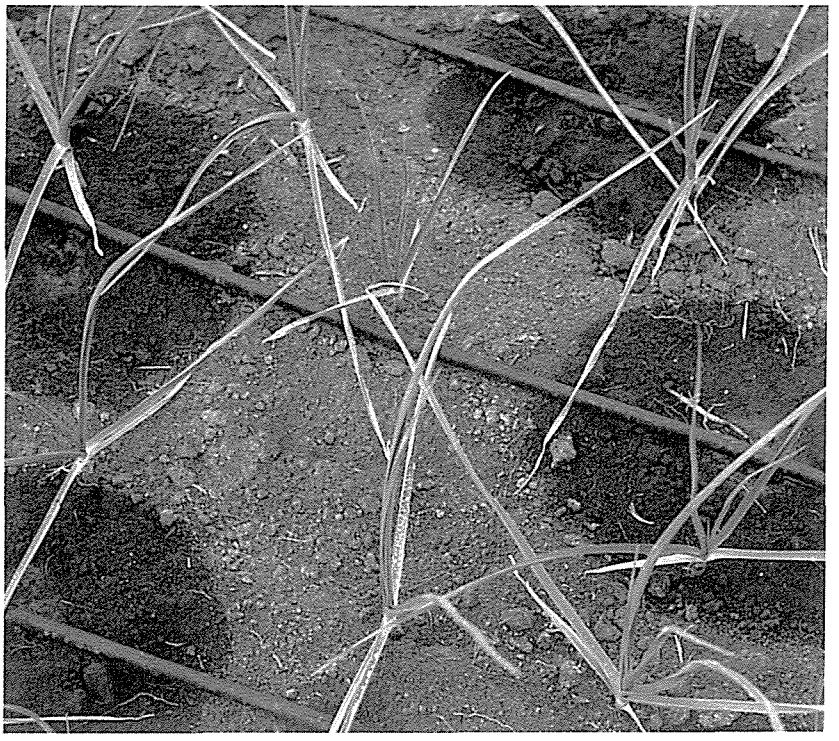
Completed projects

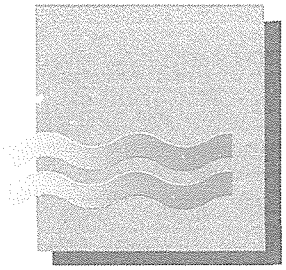
- Research on the effect of different times and intensities of internal plant moisture stress on photosynthesis, respiration and water use efficiency of certain agronomic crops (The University of the Orange Free State — Department of Agronomy/Horticulture).
- Research on the use of the soil/root conductance index and stress ratio as inputs for the determination of irrigation requirements of selected soil/plant/atmosphere systems (The University of the Orange Free State — Department of Soil Science).
- A detailed regional soil moisture deficit analysis for irrigation planning in southern Africa (The University of Natal — Department of Agricultural Engineering).
- An investigation into the condition of soils irrigated over a protracted period and an evaluation of applicable selection criteria, and reclamation and control measures (The Potchefstroom University for CHE — Department of Pedology).

Current projects

- Research on correction factors for the evaporimeter coefficients used in the irrigation scheduling of wheat (The University of the Orange Free State — Department of Agrometeorology).
- Research on improving irrigation management, based on soil water monitoring and detailed knowledge of profile available water capacities (The University of Fort Hare — Department of Soil Science).

Drip irrigation of vegetable crops.



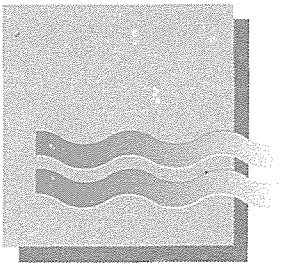


- Development of a computer program to simulate the flow of water in distribution canals (The Rand Afrikaans University — Department of Civil Engineering).
- An investigation into methods of developing operational rules for individual irrigation systems (The University of Stellenbosch — Department of Civil Engineering).
- Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State (The University of the Orange Free State — Department of Agricultural Economics).
- Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils (The Potchefstroom University for CHE — Department of Pedology and the University of Pretoria — Department of Agricultural Engineering).
- Research on the development of an adjustable low pressure flow-rate control valve for flood irrigation (The University of Pretoria — Department of Agricultural Engineering).
- Research on the practical scheduling of irrigation in the northern Transvaal (The University of the North — Department of Crop Production).
- Research on quantification and limitation of water losses associated with centre-pivot irrigation systems. (The University of the Orange Free State — Department of Agricultural Engineering in collaboration with the Department of Agronomy).
- Investigation into water use and productivity of crops under conditions of water stress and the modelling thereof (The Department of Agriculture and Water Supply — Soil and Irrigation Research Institute).
- Research on drip irrigation of tomatoes (The University of Pretoria — Department of Plant Production).

New projects

- Research on maximising irrigation project efficiency in different soil/climate/irrigation situations (The University of the Orange Free State — Department of Agrometeorology).
- Research on the storage and utilisation of rain water in the soil for the stabilisation of plant production in semi-arid areas (The University of the Orange Free State — Department of Soil Science).
- Research on the factors affecting the water use efficiency of irrigated crops, with special reference to the physiological responses of these crops (The University of the Orange Free State — Department of Agronomy and Horticulture).
- Research on estimation and evaluation of moisture stress in crops by means of remote control aerial surveillance (The University of the North — Department of Soil Science).
- Research on the water use efficiency of certain irrigated temperate pasture species (The University of Pretoria — Department of Plant Production).
- Development of a manual to be used with the IDES computer programs for the design of irrigation systems (A firm of consulting engineers: Murray, Biesenbach and Badenhorst Inc.).

6 Salinisation



In view of the fact that South Africa is not very well supplied with water, an assured water supply is always emphasised in this country. For this reason we constantly endeavour to make better use of our potential water supply and to control and reuse it better. An almost inevitable consequence of this is the deterioration of water quality in general and an increase in the salt content (salinisation) of our surface water resources in particular. Every reuse cycle contributes salt to a degree and the water therefore becomes progressively more saline. With increasing impoundment of surface water, salt concentrations rise due to evaporation. Since rising salt concentrations imply cost implications for most users, this tendency is being combated actively and attempts are being made at controlling the salt concentrations. Measures to control increases in salinity should be based on a thorough understanding of the processes which result in increased salt concentrations and loads. Appropriate research needs to gain this understanding have been identified, as a result of the coordinating role that the Commission plays amongst various organisations with an interest in salinity research and control.

The Coordinating Committee for Salinity Research which came into being in 1987, limits its activities mainly to research on salinisation from diffuse sources. Work has already started on compiling a register of salinisation research projects, which should enhance the country-wide coordination of salinity research.

The first steps have also been taken towards establishing the relative priority of different salinity research areas as well drawing up a master plan for future research.

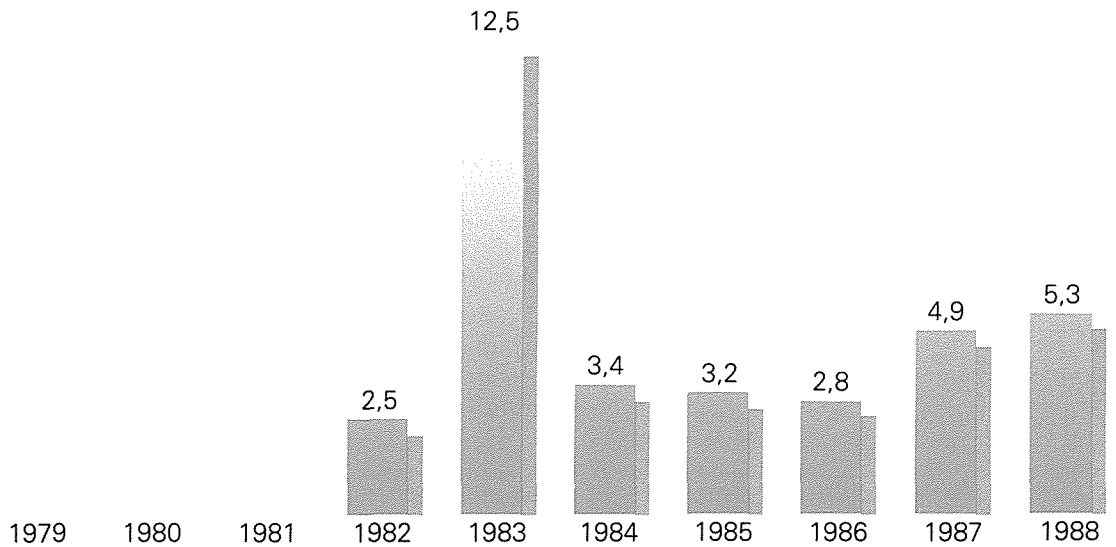
During 1988 the Commission financed eight research projects on salinisation. One project was initiated and four were completed.

A REPORT ON COMPLETED PROJECTS

Research on the contribution of mine dumps to mineral pollution in the Vaal Barrage

The research was carried out in three phases, in terms of a tripartite agreement between the WRC, the Department of Water Affairs and a firm of consulting engineers. Three mine dumps were selected in consultation with the Chamber of Mines for a monitoring study over a period of three years.

Phase one comprised the installation of a monitoring network for surface and ground water on a sand-pile and two slimes dams. During phase two data were collected and analysed. During phase three an inventory of the 273 mine dumps in the study area was compiled, as well as the extrapolation of the results of phase two to all mine



Funding of research on Salinity expressed as a percentage of total WRC research expenditure (1979 to 1988).

dumps, in order to estimate the total contribution from all the mine dumps to the salt load of the Vaal Barrage.

The sand-pile delivered significant quantities of dissolved salts (e.g. 2 300 t in 1985) to the water environment, while the contribution of the slimes dams to the salt loads was negligible. The major contribution of the sand-pile to the salt load can be attributed mainly to seepage water.

Extrapolation of the results has shown that the mine dumps in the Vaal Barrage area contributed a pollution load of approximately 50 000 t in 1985, of which an unknown quantity reached the Vaal Barrage. If the Department of Water Affair's estimate of the total pollution load in the PWV area is accepted, viz. approximately 400 000 t/a, the contribution of the mine dumps would amount to about 12,5%.

Research on integrated studies of the generation of runoff, solutes and sediment in the tributary catchments of the Great Fish River

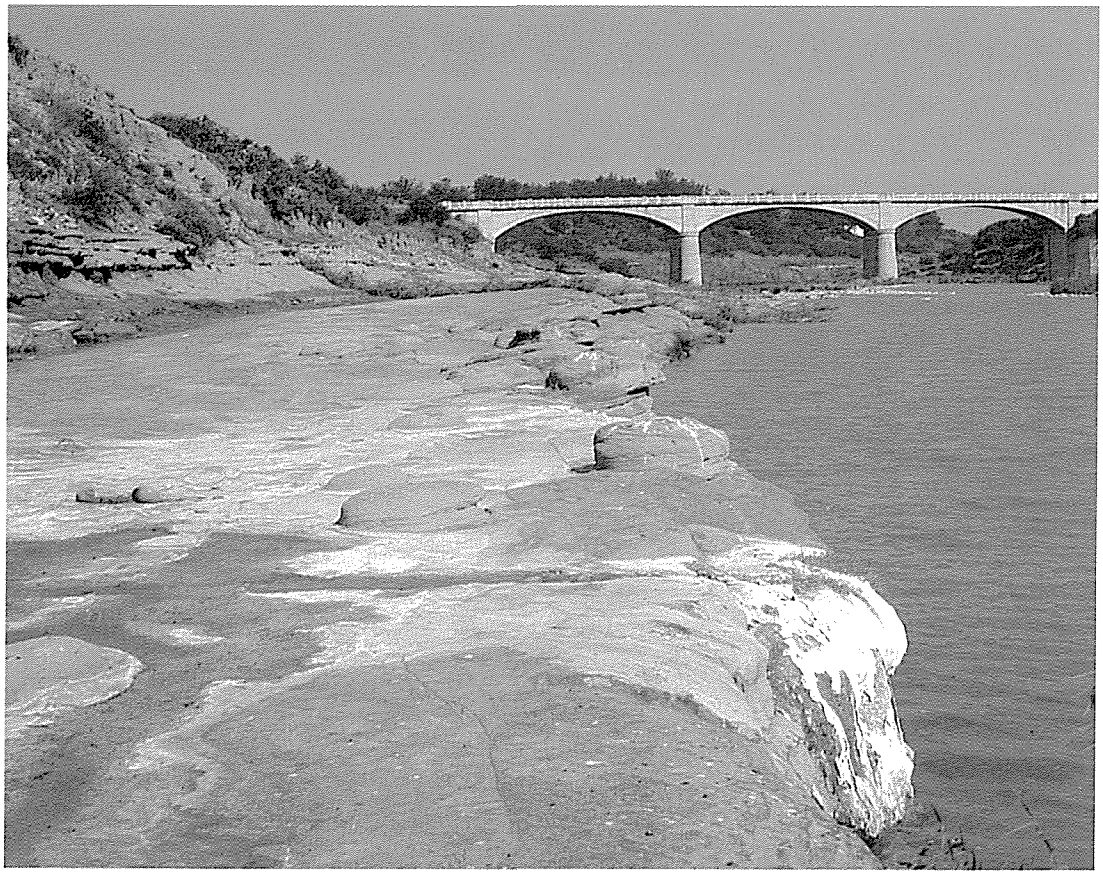
The aim of this research, which was carried out by Rhodes University, was to establish the influence of natural rainfall on the generation of runoff, salts and sediments in a number of subcatchments of the Ecca River, a tributary of the Great Fish River. This research over five years coincided with a period of abnormally low rainfall in the area. Important insight into the salt-producing mechanisms and hydrology of the semi-arid areas could nevertheless be gained. Although the project has been completed, the monitoring of flow events is being continued as part of the Rhodes University project in the Coerney River, so that the validity of the present conclusions can be tested over a longer period and with a wider range of rainfall events.

Research on detailed geohydrological investigations in the Poesjenels River catchment in the Breë River valley, with special reference to mineralisation

The objective of this project, carried out by the University of Stellenbosch, was to trace the flow routes of irrigation return flow to the river and to establish the relative contribution of processes in the root zone and underlying material to salinisation of the river. It was found *inter alia* that less than 10% of the total water input leaves the Poesjenels River valley and that the salt content of the river is at times very high. The salt concentration in the river reaches a peak at the start of the winter rains and is mostly at its lowest at the end of the rainy season. Furthermore it was confirmed that the Bokkeveld shale, which underlies the valley, contains large quantities of salts in the weathered and unweathered state. Potentially these salts could be leached to the river. In parts which have been irrigated for a long time, salts have already been leached considerably while large quantities are mobilised when virgin soil is put under irrigation. Water source typing by means of radio isotopes indicates that water indeed percolates from the saltless Tafelberg sandstone in the mountains along fissures in the Bokkeveld shale to the river, and that salts are dissolved in the process. The resulting contribution to the salt load of the river is, however, far less than that which can be attributed to mobilisation as a result of irrigation, especially in the case of virgin soil.

A pilot study of the irrigated areas served by the Breë River (Robertson) irrigation canal

This pilot study, carried out by a consulting engineering firm and the Department of Water Affairs, aimed at establishing whether it would be practically or economically possible to do the measurements which would be required to calculate a water and salt balance for an irrigated area. To a large extent this objective was achieved. It was found *inter alia* that substantial amounts of water are lost due to canal losses and leakage from storage dams. It was also found that the total amount of water applied, although not necessarily the scheduling thereof, shows good agreement with the theoretical crop water requirements. Results which have been collected, have been used as input data for the IRRISS model which has been developed by the Department of Water Affairs. This model has proved to be a powerful expedient for the calculation of water and salt balances of irrigation schemes. It has been calculated that 5,2 ×



Irrigation return flow originating from irrigated land seeping back over bedrock to the Sundays River.

Acid drainage area next to a colliery dump.

10^6 m^3 water (which comprises 38% of the applied irrigation water) with an associated salt load of $6,2 \times 10^6$ kg, drained out of the 1 064 ha irrigated area as irrigation return flow during the irrigation period.

DISCUSSION OF A NEW PROJECT

Research on the evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses

This project is being carried out over two and a half years by a firm of consulting engineers in terms of an agreement with the Commission.

That portion of irrigation water which is not taken up by plants, seeps through the soil and underlying material and flows back partly to rivers and partly recharges underground water. The volume and composition of this so-called irrigation return flow influence the water quality of several rivers. In general the measures which can be taken to reduce and to control excessive seepage losses (and the concomitant salt load) are the same as those taken to improve the water use efficiency of irrigation water. The purpose of this project was to determine the possibility of controlling salinisation of the Breë River by more effective scheduling of irrigation and reduced seepage losses. For this reason the amount of seepage which occurs in practice will be determined as quantitatively as possible, using a representative sample of irrigation systems in the valley. The part played by the quality of irrigation design and choice of system, as well as the scheduling of water application, will also be determined. From this it should be possible to identify possible difficulties and to make proposals to adapt the present irrigation management and design procedures for better water utilisation and more efficient control over drainage.

LIST OF RESEARCH PROJECTS

Completed projects

- Research on the contribution of mine dumps to mineral pollution in the Vaal Barrage (The Department of Water Affairs, and a firm of consulting engineers: Steffen, Robertson and Kirsten Inc.).
- Research on integrated studies of the generation of runoff, solutes and sediment in the tributary catchments of the Great Fish River (Rhodes University — Department of Geography).
- Research on detailed geohydrological investigations in the Poesjenels River catchment in the Breë River valley, with special reference to mineralisation (The Department of Water Affairs — Division of Geohydrology, and the University of Stellenbosch — Department of Geology).
- A pilot study of the irrigated areas served by the Breë River (Robertson) irrigation canal (A firm of consulting engineers: Murray, Biesenbach and Badenhorst Inc.).

Current projects

- Research on the inhibition of bacterial oxidation of pyrite and concomitant acid mine water (The Chamber of Mines and the University of Stellenbosch — Department of Microbiology and Virology, and the Institute for Polymer Science).
- Research on an evaluation of the abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone (The University of Stellenbosch — Department of Soil and Agricultural Water Science).
- Hydrosalinity studies in the Eastern Cape (Rhodes University — Department of Geography).

New project

- Research on the evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses (A firm of consulting engineers: Murray, Biesenbach and Badenhorst Inc.).

7 Eutrophication

Eutrophication is a process whereby the water environment, mainly impounded water, is enriched with plant nutrients, such as nitrogen compounds and phosphates. The most conspicuous consequence of this enrichment is the prolific growth of aquatic plants, including algae. This luxuriant growth is not only aesthetically unattractive but also creates problems when the water is used as drinking water. The Commission has been supporting research in this field for many years now and several aspects have been investigated. Some of these results have indicated that phosphate is the most important nutrient source and that control of this nutrient could make an important contribution to the management of eutrophication. The Department of Water Affairs has intensified their effort to control the discharge of phosphates by implementing an effluent phosphate standard of 1 mg/ℓ as P in certain sensitive areas. One such area is the Hartbeespoort Dam and its catchment.

A REVIEW OF SOME CURRENT PROJECTS

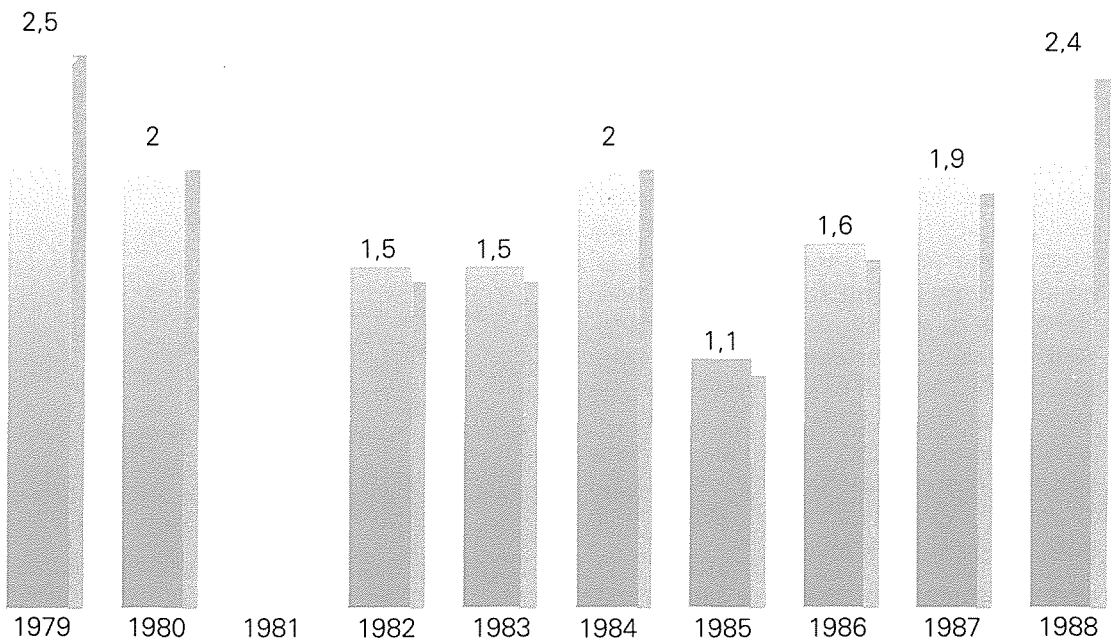
Evaluation of the impact of the phosphate standard on the water quality and trophic status of Hartbeespoort Dam

The project is centred on the regular collection of data on the phosphate status of water flowing into Hartbeespoort Dam and on the phosphate and algal content of the dam. Information on phosphates released by effluent treatment works in the catchment of Hartbeespoort Dam is made available by the Department of Water Affairs, which has also recently assumed responsibility for collecting the data on the inflows.

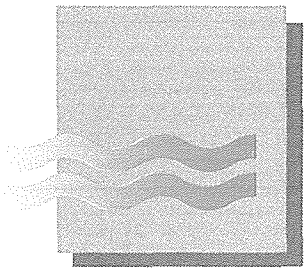
Due to the involvement of several organisations, directorates and subdirectorates, release of information on the inflows and effluents has been delayed. In the dam itself there have been steady declines in orthophosphate-phosphorus concentrations since 1985 (Table 1). The declining trend is most clearly evident in the deep-water samples taken in both winter and summer and in those samples taken of the surface waters in the winter. At the surface the trend is less marked in summer, due to the impact of direct rainfall and large inflows.

The response of the phytoplankton has been variable and the summer chlorophyll values have recently increased, despite the lower phosphate concentrations.

In 1988 there has been a marked decline in the winter chlorophyll concentrations, but in previous years mean concentrations had been variable and not related to phos-



Funding of research on Eutrophication expressed as a percentage of total WRC research expenditure (1979 to 1988).



phate concentrations. This lack of a direct relationship between phosphate concentrations and abundance of phytoplankton reflects the fact that for phytoplankton growth, phosphate is not yet a limiting factor.

The phytoplankton abundance from summer 1986/87 onwards can undoubtedly be linked to the fact that rainfall has been above average since then, so that by the end of summer 1986/87 and 1987/88 the dam spilled, carrying away the summer growth of *Microcystis*. Certainly *Microcystis* was more completely spilled in autumn 1988 than in autumn 1987, which at least in part accounts for the low winter 1988 chlorophyll *a* concentration. The high chlorophyll *a* concentration in 1987 and 1988 may be related to the greatly increased surface area of the dam.

In summary the impact of the phosphate standard on ambient ortho-phosphate concentrations in Hartbeespoort Dam is now evident, despite the fact that compliance with the standard is not yet complete. The reduction in phosphates in the dam is insufficient to have reduced the abundance and altered the species composition of the phytoplankton.

Development of management orientated models for eutrophication control

The aim of this study is to develop mathematical models which simulate eutrophication processes and their effect on algal growth as an aid to making management decisions. These models are being incorporated into a user-friendly decision support system (DSS) to facilitate the application thereof. The output of the DSS will forecast the typical phosphate and resulting algae concentrations of an impoundment due to various catchment management options under consideration for the catchment. The DSS has progressed to the extent that the Department of Water Affairs has already used it as an aid to revise decisions concerning the implementation of the 1 mg/ℓ phosphate-P standard in sensitive catchment areas.

Several aspects aimed at refining the mathematical models and improving their user-friendliness, as well as the usefulness of the DSS, will receive attention during the remaining term of the project.

DISCUSSION OF A NEW PROJECT

The quantification of the effects of land use on runoff quality in selected catchments of Natal

Development trends and expected land-use changes in the catchment areas of the Mgeni River system are believed to constitute a serious threat to the long-term water quality in general and specifically as far as eutrophication of the river system is concerned. To a large degree we still lack the knowledge with which to predict the consequences these land-use changes may have on water quality. As part of this three-year project the CSIR will attempt to quantify the effects of land use on runoff water quality. The research will be carried

Table 1: Mean phosphate-phosphorus values (µg ℓ^{-1}) recorded in Hartbeespoort Dam in summer (Dec., Jan., Feb.) and winter (July, August, Sept.) in recent years

Year	Summer	Winter
Bottom waters		
1984/85	781	
1985		601
1985/86	647	
1986		407
1986/87	512	
1987		269
1987/88	490	
1988		174
Surface waters		
1984/85	351	
1985		402
1985/86	183	
1986		354
1986/87	294	
1987		196
1987/88	127	
1988		124

out in close collaboration with the Universities of Natal and Zululand that will be conducting complimentary research projects. The aims of this project are to characterise and compare runoff water quality and loads from different types of land use, to synthesise the collected data into a suitable form for inclusion into a proposed Mgeni catchment water quantity/quality model to be developed by the University of Natal, and to investigate the need to establish a longer term monitoring programme on one or more selected catchments with specific land uses, in order to assess the spatial, temporal and development effects on water quality.

LIST OF RESEARCH PROJECTS

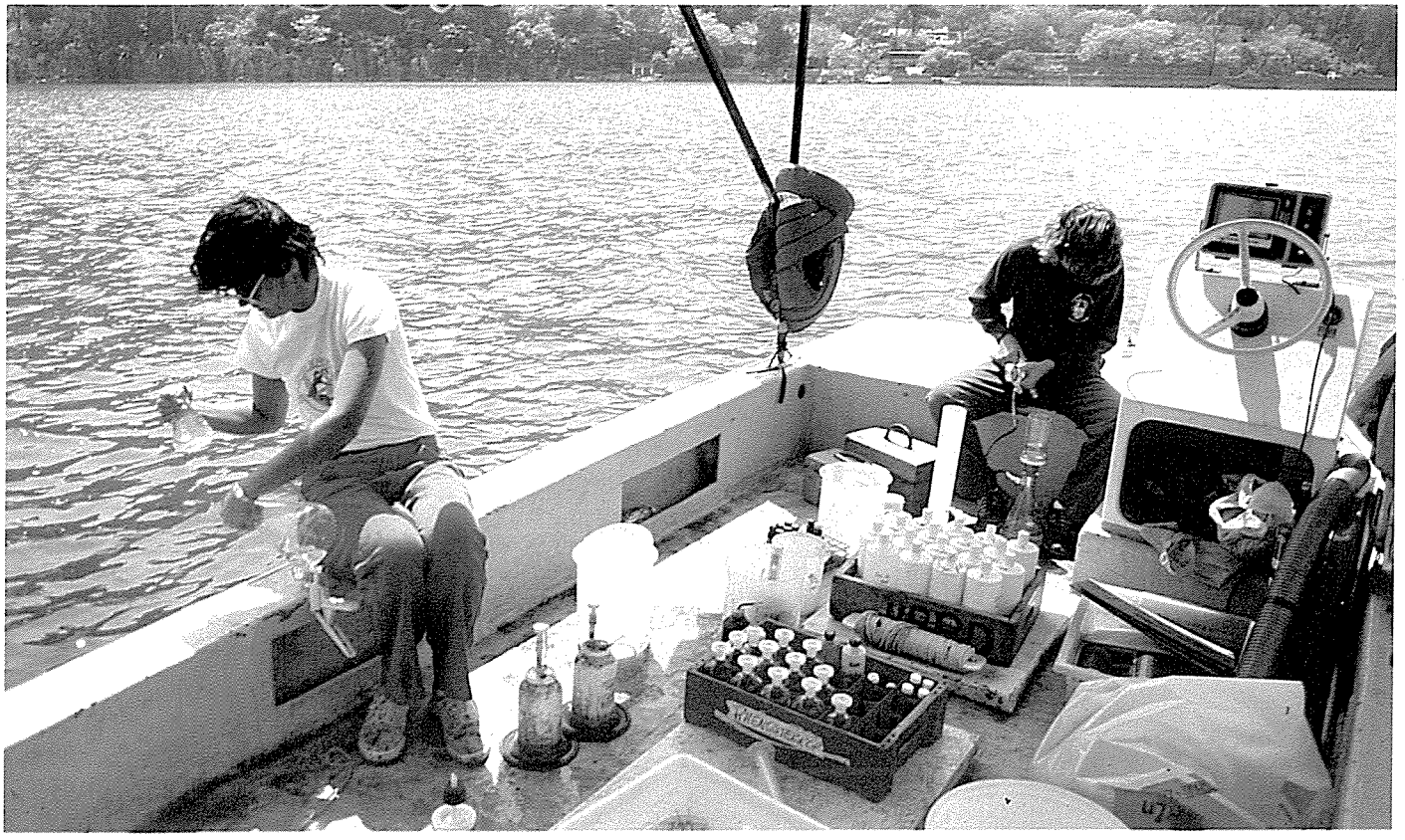
Current projects

- Evaluation of the impact of the phosphate standard on the water quality and trophic status of Hartbeespoort Dam (CSIR — Division of Water Technology).
- Development of management-orientated models for eutrophication control (CSIR — Division of Water Technology and the Department of Water Affairs).
- The development of phosphate export models for catchments (CSIR — Division of Water Technology).
- Research on the effective use of water by means of an algal-aqua culture system (The University of the Orange Free State — Limnology Unit).

New project

- The quantification of the effects of land use on runoff quality in selected catchments in Natal (CSIR — Division of Water Technology).

Sampling Hartbeespoort Dam water.



8 Municipal waste water

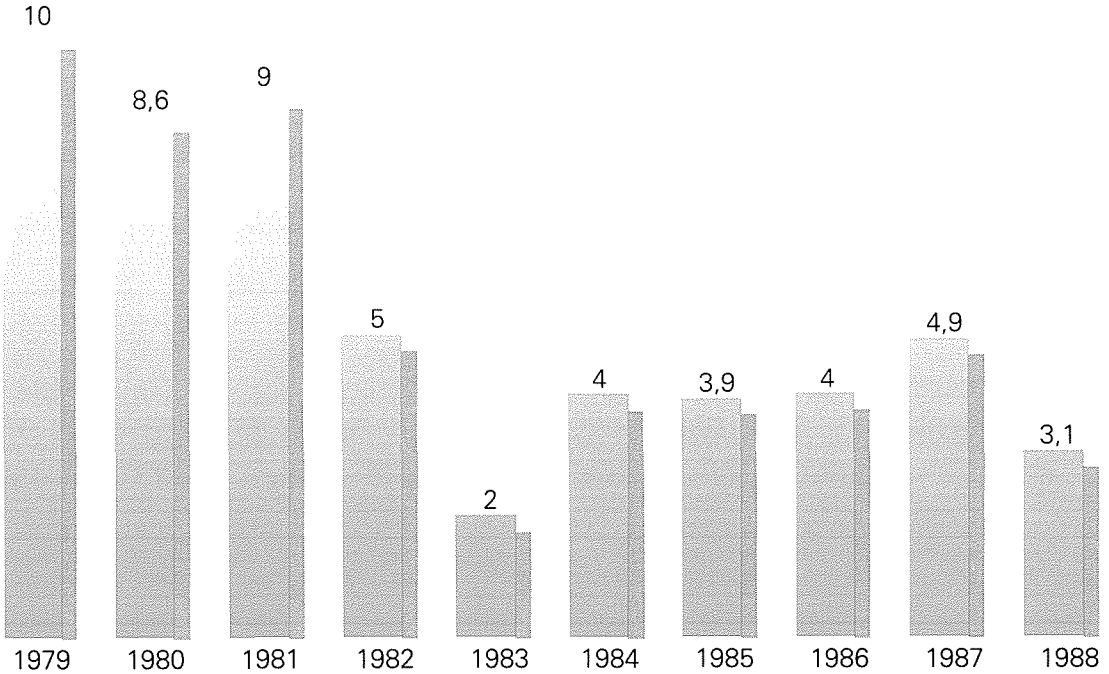
Water that is not used consumptively in the municipal and domestic sector must be returned to the water environment. Before it can be returned however, the water, now polluted from use in this sector must be treated to standards prescribed by regulations in terms of the Water Act. These regulations prescribe different standards for different areas, depending upon their sensitivity to pollution. Of particular importance in this respect is the standard for phosphate implemented in 1985 for sensitive catchments. Strict enforcement of the 1 mg/ℓ P standard will be applied in catchments of the Crocodile River, the Vaal Barrage, and the Inanda, Shongweni and Laing Dams.

Research financed by the Commission in the municipal waste-water treatment field has been aimed at the prevention of pollution from the discharge of effluents. Specific areas of immediate concern have been given a high priority and include the removal of plant nutrients (phosphates and nitrates) from effluents. These plant nutrients cause deterioration in water quality and reduce its suitability for most uses. Prolific growth of algae and other aquatic plants seriously hampers recreational use as well as the treatment and conveyance of water.

Various approaches have been adopted in addressing this problem and include nutrient removal methods which are purely biological, methods which rely on the addition of chemicals to precipitate the undesirable phosphates from the effluent, crystallisation methods, electrochemical methods and combinations of the above.

Since waste-water treatment plants must also produce a final effluent which complies with a number of other criteria before discharge to the water environment, use of a nutrient removal process must not have any deleterious effect on other criteria. The addition of chemicals for the removal of phosphate for example, will increase the total dissolved salts of the effluent. Where the total dissolved salts build-up is a problem, chemical phosphate removal would not be desirable. Similarly the use of biological nutrient removal in the activated sludge process can cause severe sludge bulking under certain conditions resulting in carry-over in the final discharge of suspended solids far in excess of the limit imposed by the standard.

The Commission currently sponsors nine research projects in this field.



Funding of research on Municipal Waste Water expressed as a percentage of total WRC research expenditure (1979 to 1988).

PHOSPHATE REMOVAL IN WASTE-WATER TREATMENT

The Commission supports four research projects in this respect.

Research on enhancement of biological phosphate removal from sewage by altering process feed composition

Experience in Johannesburg has shown that the continuous and reliable removal of phosphates to the required standard is critically dependent on having an adequate supply of readily biodegradable chemical oxygen demand (COD) present in the influent. The concentration of readily biodegradable COD naturally present in the influent sewage was successfully augmented by the fermentation and recycle of primary sludge for the elutriation of soluble organics compounds. During the course of this one-year extension of the original contract with Johannesburg considerable experience was also gained with on-line measurement of phosphates, nitrates, ammonia and alkalinity of effluents and subsequent use and analysis of the data. Simultaneously with full-scale experimentation, a number of fundamental studies were carried out into the dominant phosphate-removing bacteria and enzyme activity in the synthesis of polyphosphate. Fundamental findings were also applied to improve the stability of biological phosphate removal in activated sludge plants in Johannesburg.

Research on biological excess phosphate removal

The final report on this work, undertaken in terms of a contract between the Commission and the University of Cape Town, was accepted by the Commission during the year. The report was officially handed over to the Commission at a technology transfer symposium held in Johannesburg in October. The symposium was held to serve as a discussion forum and featured the findings of the work funded in terms of this contract and the work by Johannesburg on biological phosphate removal. The principal objective of this contract was to develop a kinetic model for biological excess phosphate removal in biological nutrient removal plants with a view to improving the technology concerned. Four separate sub-projects were completed in the study, viz. biological excess phosphate removal system performance, substrate description, modelling of biological excess phosphate removal and non-polyphosphate activated sludge modelling.

Research on phosphate crystallisation in activated sludge systems

Due to a number of inherent disadvantages associated with chemical phosphate removal, such as cost and unavailability of chemicals, additional sludge production and increased total dissolved salts in the effluent, and problems that can arise with biological phosphate removal, this investigation was launched by the CSIR to assess the feasibility of phosphate crystallisation.

Studies into phosphate crystallisation have been successfully carried out elsewhere; however these studies were all carried out either with synthetic feed in batch tests or after secondary settlement of sewage.

Research on electrochemically produced metal coagulants for the purification of polluted water

This one-year study was undertaken by the University of Pretoria during 1987 and involved an evaluation of the most important physical and chemical factors that affect the kinetics of electrochemical production of coagulants for the precipitation of phosphate and other contaminants. The study also involved development of a practical electrode system and application of the principle in practice. A final report on the work is due to be released in 1989.

ACTIVATED SLUDGE BULKING

The Commission supports one project in this field.

Research, development and full-scale evaluation of preventative and remedial methods for the control of activated sludge bulking

Activated sludge bulking is a serious and common operational problem in nutrient removal activated sludge plants in South

Africa and results in the carry-over of suspended solids into the final effluent discharges from sewage works. The main objectives of this work undertaken by the University of Cape Town were to identify the filamentous organisms causing bulking, evaluate non-specific bulking control with chlorination, and evaluate specific bulking control procedures for long sludge age systems.

A DISCUSSION OF NEW PROJECTS

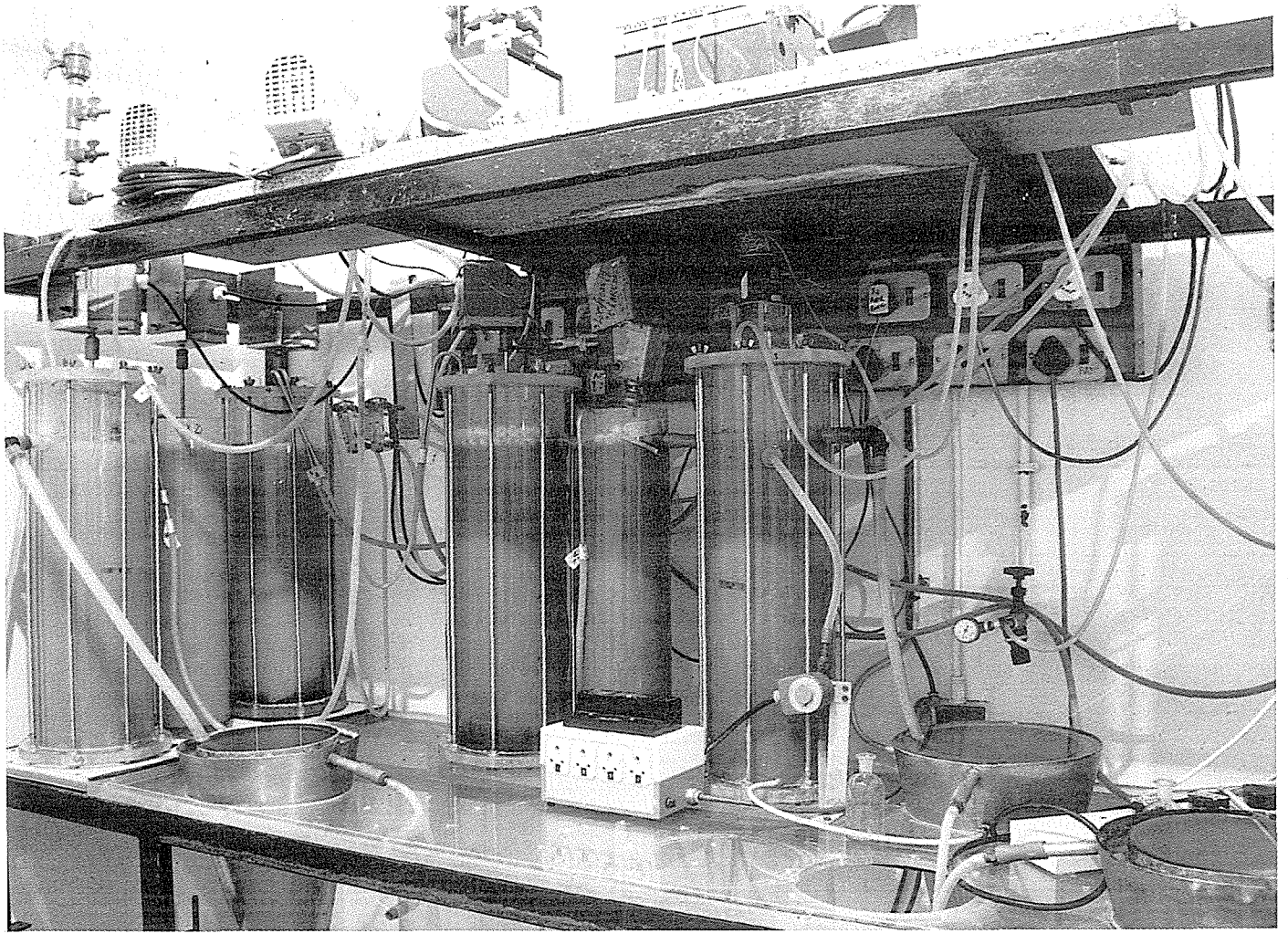
Research on pelletisation in upflow anaerobic sludge bed (UASB) systems

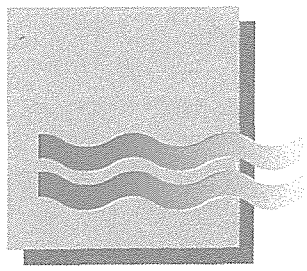
This new project commenced in January 1988 and is being undertaken by the University of Cape Town.

The research into anaerobic fermentation will focus on the phenomenon of pelletisation, or granulation, which has been observed in upflow anaerobic sludge bed (UASB) systems treating substrates that contain a high portion of carbohydrates. No pelletisation has been observed in completely mixed systems treating this substrate. The following principal objectives are included in the study:

- to check the validity of the hypothesis on pelletisation or non-pelletisation by experimentally operating UASB systems with carbohydrate, proteinaceous and oily wastes;
- to formulate models for pH control in both completely mixed reactors and UASB systems;
- to set up kinetic models for the pelletising and non-pelletising processes; and

Laboratory-scale modified Bardenpho activated sludge units used in continuous studies on calcium phosphate crystallisation.





- to optimise the UASB system and develop operational and control strategies.

The work will be undertaken over three years on laboratory-scale UASB systems and where possible, collaborative work will be done on full-scale operating UASB systems.

Consolidation of activated sludge and water chemistry research

This new three-year project commenced in January 1988 and is being undertaken by the University of Cape Town. The purpose of the project is to consolidate work undertaken by the University over the past fifteen years on the activated sludge process, biological nutrient removal from waste water and on water chemistry. The significant advances in these fields, brought about by research in South Africa, have led to an improved understanding and rationalisation of the different components of the technology, particularly that of activated sludge, and allow a more integrated approach. It was considered opportune now to write a number of technology transfer information documents and papers for the water and waste-water industry. Included in these information documents will be a revision of the Commission's design guide *Theory, Design and Operation of Nutrient Removal Activated Sludge Processes,* which will take the form of a supplement to the guide.

Research on phosphate fixation in waste waters by means of controlled struvite formation

This new research project commenced in January 1988 and is being undertaken by the CSIR over three years. The primary objective of the proposed research is to investigate the feasibility of immobilising dissolved orthophosphate in nutrient removal activated sludge plants, to prevent the re-release of phosphates, by means of magnesium ammonium phosphate (struvite) formation. The research will be focused on the treatment of liquors arising during anaerobic digestion of the phosphate-rich sludge produced in biological nutrient removal plants as well as on the phosphate-enriched mixed liquor within the activated sludge plant itself. Specifically the research will entail verification of the kinetics of struvite formation, design and operating criteria for a struvite precipitation/crystallisation system and pilot-scale evaluation of struvite formation.

Research on chemical augmentation of biological phosphate removal

This new three-year project commenced in July 1988 and is being undertaken by the City Council of Johannesburg. Two aspects will be covered in the research project. The first of these is to investigate the supplementation of biological phosphate removal with in-plant addition of chemicals. This will be to supplement biological phosphate removal when achievement of the 1 mg/ℓ P standard is difficult. The work will be undertaken at full scale on waste-water treatment plants with different influent characteristics.

The second aspect is an investigation into phosphate precipitation from supernatant liquor from anaerobic digesters at nutrient removal waste-water treatment plants. Phosphate removed biologically in the activated sludge plant will be released under anaerobic conditions when the waste sludge undergoes anaerobic digestion. The phosphate released into the digester supernatant liquor will be precipitated out as magnesium ammonium phosphate.

LIST OF RESEARCH PROJECTS

Completed projects

- Research on biological excess phosphate removal (The University of Cape Town — Department of Civil Engineering).

Current projects

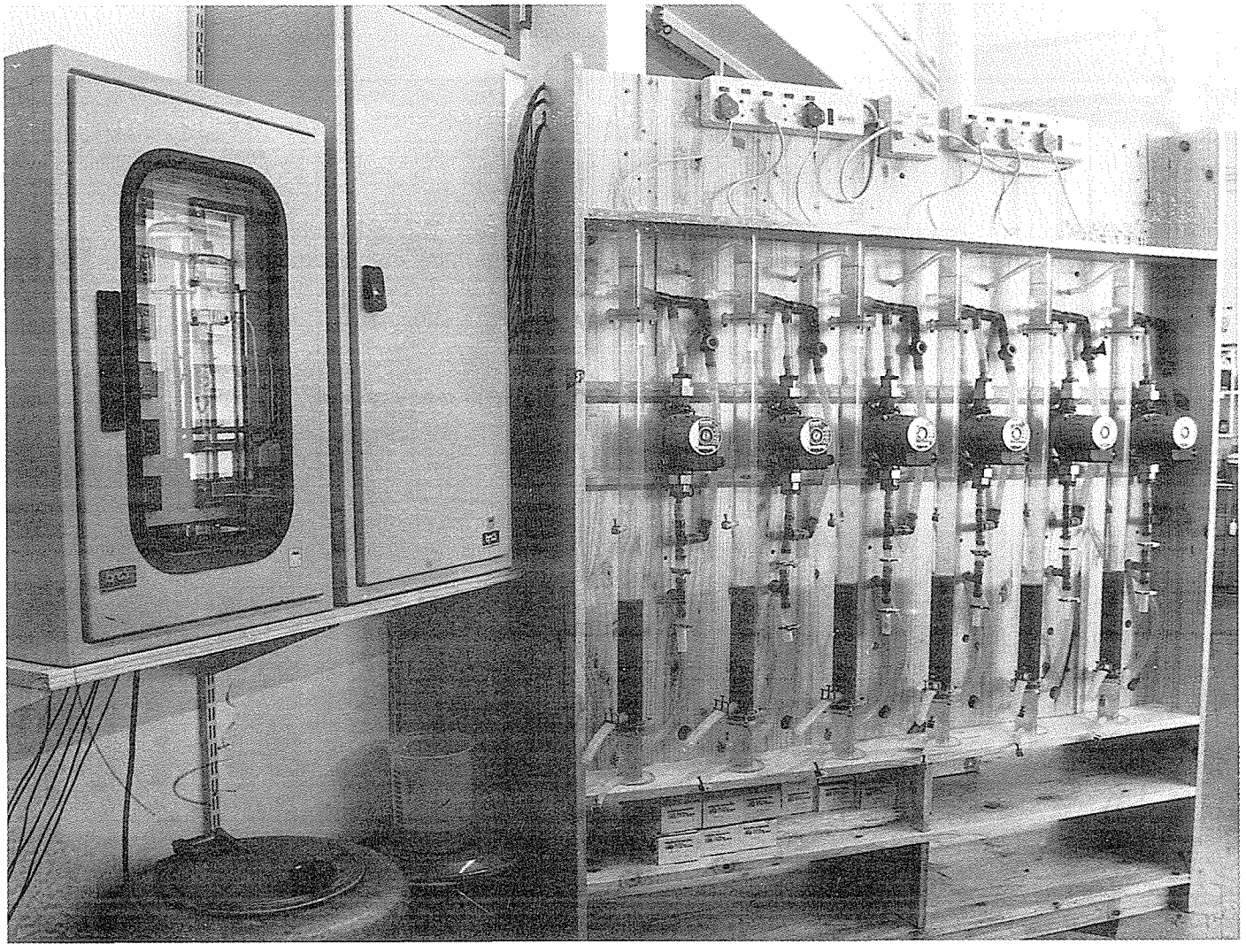
- Research on enhancement of biological phosphate removal from sewage by altering process feed composition (The City Council of Johannesburg).
- Research, development and full-scale evaluation of preventative and remedial methods for the control of activated sludge bulking (The University of Cape Town — Department of Civil Engineering).

- Research on phosphate crystallisation in activated sludge systems (The CSIR — Division of Water Technology).
- Research on electrochemically produced metal coagulants for the treatment of polluted water (The University of Pretoria — Department of Chemical Engineering).

New projects

- Research on chemical augmentation of biological phosphate removal (The City Council of Johannesburg).
- Research on pelletisation in upflow anaerobic sludge bed (UASB) systems (The University of Cape Town — Department of Civil Engineering).
- Research on phosphate fixation in waste waters by means of controlled struvite formation (The CSIR — Division of Water Technology).
- Consolidation of activated sludge and water chemistry research (The University of Cape Town — Department of Civil Engineering).

pH Control unit (left) and batch reactors (right) used in studies on calcium phosphate and struvite crystallisation.



9 Sewage sludge treatment and disposal

Ten years ago the Commission embarked upon a programme of research aimed at addressing the problems associated with sewage sludge treatment and disposal. With the particular conditions that exist in South Africa, it was not a simple matter to adopt sludge treatment and disposal procedures being used in other parts of the world, in the hope that they would apply equally well here. Health restrictions on the one hand, climatic conditions and long distances to farm-land on the other, resulted in no outlet for sludge, either treated or untreated, being readily available. Disposal of untreated sludge on land was not permissible. The minimum treatment at any works was stabilisation of the sludge. This having been effected, the problem was to find a suitable outlet for the sludge in stabilised form. Invariably the end result was disposal on land at the works itself.

After a study by consultants who reported to the Commission on practices and trends in countries abroad, and a study of the specific problems in the metropolitan areas of South Africa, a master plan for sludge management was developed. Several successful research projects launched under this umbrella have opened up new sludge disposal or sludge utilisation routes for various parts of the country.

Research is still ongoing with three projects.

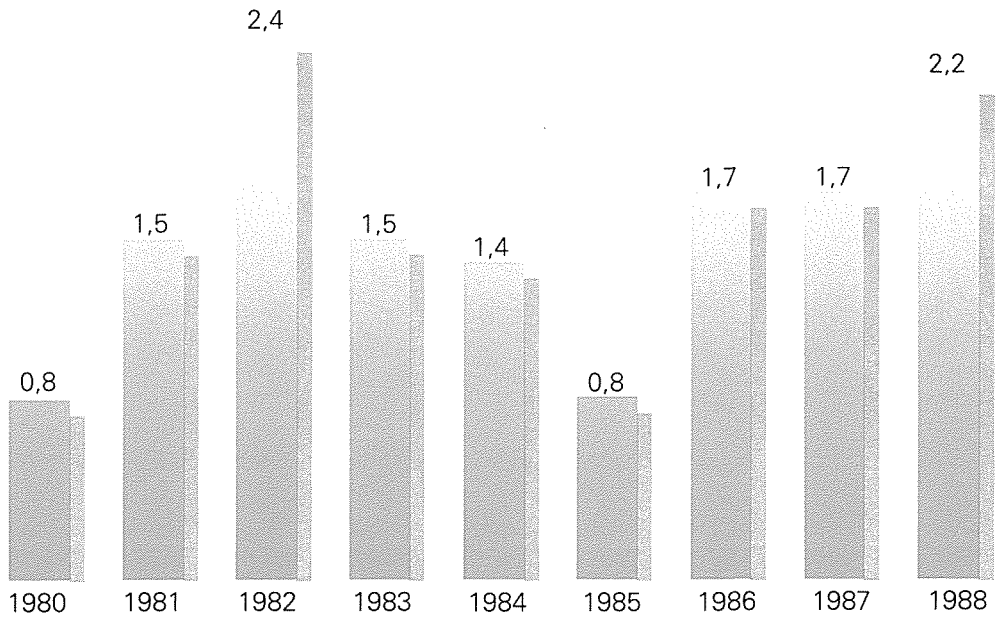
A REVIEW OF SOME CURRENT PROJECTS

Research on the chemical characterisation of South African municipal sludges

The aims of this three-year project being undertaken by the CSIR are:

- to conduct a survey of the occurrence of inorganic chemical contaminants and nutrients in South African sewage sludges;
- to establish the most suitable methods for analysis of these contaminants; and
- to contribute, in conjunction with other studies of the Division of Water Technology and information available from overseas, towards the preparation of guidelines for the application of sewage sludge to agricultural land.

During the final year samples of sludge from the remaining sewage works to be surveyed were obtained and analysed for inorganic contaminants and nutrients. A final report on the work is expectd early in 1989.



Funding of research on Sewage Sludge expressed as a percentage of total WRC research expenditure (1980 to 1988).

Research on the evaluation and optimisation of the process of dual digestion of sewage sludge

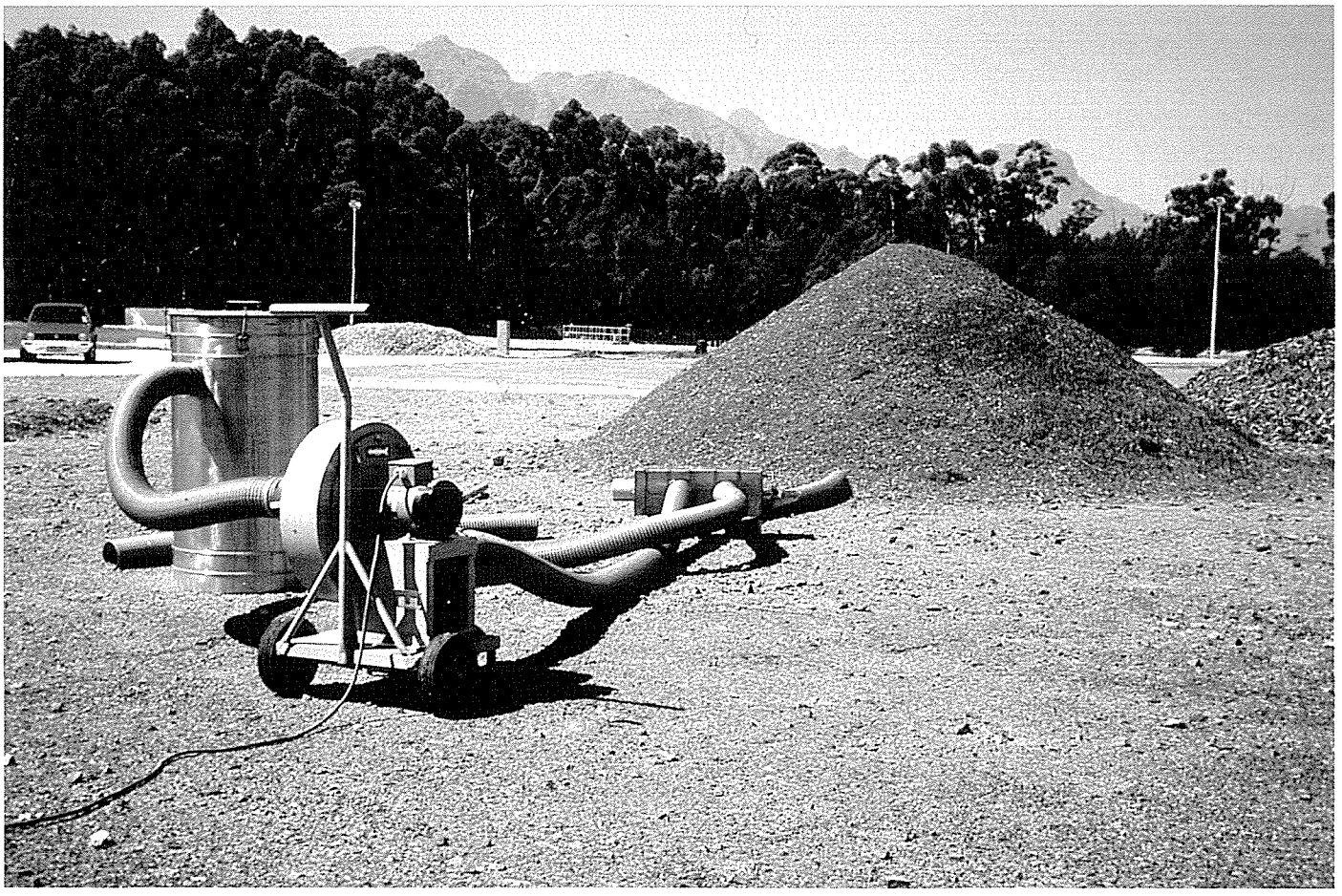
This project is being undertaken jointly by the CSIR and Milnerton Town Council. During the year under review the full-scale 45 m^3/d plant has been operating successfully at Milnerton. The aerobic reactor, once all the teething problems had been ironed out, has been operating faultlessly. The anaerobic reactor, only brought into operation when the aerobic reactor had proved that it could be operated for uninterrupted periods, began functioning during the first half of the year.

The research being conducted at Milnerton and due to end in December 1989, has shown that the process offers an alternative to other sludge stabilisation/disinfection processes. The degree of disinfection achieved by operating the aerobic reactor at temperatures ranging between 55 °C and 65 °C has been consistently good.

Performance evaluation of forced aeration composting of sewage sludge

This project, being undertaken jointly by the Municipality of Stellenbosch and the CSIR, commenced late in 1987 and is due for completion at the end of 1988. In terms of an agreement with the Municipality, the Commission has arranged for the research expertise at the Division of Water Technology (DWT) to be made available to assist with the design and operation of the process and to scientifically study the performance of the Stellenbosch plant. The plant has been in operation since December 1987 and the unit processes involved, such as dewatering of the raw sludge, mixing, aeration, maturation and screening, have been optimised as far as possible.

Work undertaken previously at pilot scale by the DWT has been successfully transferred to a full-scale municipal plant, which will now serve as a demonstration plant for other municipalities and interested parties.



Forced aeration composting of sludge: An effective sludge disinfection and stabilisation process incorporating the use of wood chips which are screened out on completion of the process.

DISCUSSION OF A NEW PROJECT

Research on the preparation of engineering design guidelines for artificial wetlands for waste-water treatment

A further project being undertaken jointly by the CSIR and a firm of consulting engineers, is aimed at the preparation of guidelines for the engineering aspects in the design of wetlands, to be used in rural sanitation.

The aims of the project, which is scheduled to run for one year, are:

- to evaluate the use of artificial wetlands as an alternative waste-water treatment technology under South African conditions and thus to identify appropriate applications for the system;
- to conduct comparative economic appraisals to assess/ensure the viability of artificial wetlands for various applications;
- to prepare engineering design guidelines for the construction and use of wetland systems in this country; and
- to initiate a framework for the continued collection and evaluation of data with a view to periodically updating the design guidelines.

The need for sewage treatment processes for small communities which require only minimal input by unskilled operators and supervisory staff has long been known. Some degree of success has been achieved with the design and construction of more fundamental, yet adequate, sewage treatment facilities. One such process is that of artificial wetlands, a potentially reliable and fundamental process for treatment of secondary effluents and for the removal of nutrients from these effluents.

However, whilst wetlands may have considerable merit for future application, little is known of the economics of the system in comparison with present alternatives, or of the engineering design criteria to be used under South African conditions.

A computer method will be developed for the rapid economic assessment of wetland systems for various applications.

LIST OF RESEARCH PROJECTS

Current projects

- Research on the chemical characterisation of South African municipal sludges (CSIR — Division of Water Technology).
- Research on the evaluation and optimisation of the process of dual digestion of sewage sludge (The Town Council of Milnerton and the CSIR — Division of Water Technology).
- Performance evaluation of forced aeration composting of sewage sludge (The Municipality of Stellenbosch and the CSIR — Division of Water Technology).

New project

- Research on the preparation of engineering design guidelines for artificial wetlands for waste-water treatment (The CSIR — Division of Water Technology).

10 Marine disposal of effluents

Due to the favourable ocean currents around the South African coastline, considerable use has been made of the marine environment for the disposal of a number of different effluents. These range from fully treated effluents which could be discharged to any river system to sewage which has only undergone a minimum of pretreatment. The ocean has a large capacity to absorb particular wastes and is indeed assimilating wastes that are carried to the sea by rivers. Strict control, however, exists to ensure that only wastes that can be effectively absorbed by the marine environment are discharged. In this respect, water quality criteria for coastal areas were developed and published in 1984 by the Marine Pollution Committee of the South African National Committee for Oceanographic Research (SANCOR). These criteria have provided useful design objectives for marine disposal systems.

A REVIEW OF SOME CURRENT PROJECTS

Research on marine disposal practice in South Africa

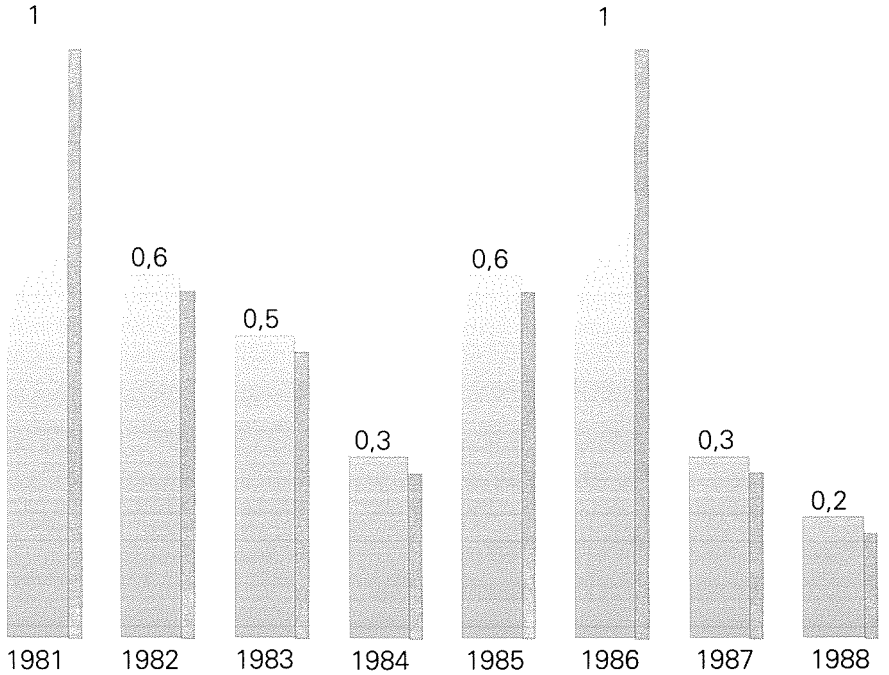
Due to stricter control measures for the discharge of effluents to the marine environment, attention has recently been given to the construction of more efficient marine disposal systems for industrial and domestic wastes. In order to assist prospective designers of these systems as far as possible, the Commission entered into an agreement with the CSIR to compile a publication that would document descriptive and technical details of known marine discharges around the South African coastline. The publication would be compiled in such a way that the successes and failures of present practice could be reviewed to ensure safe and circumspect design and operation in the future.

Seventy-five marine discharges were reviewed in the investigation. Details such as problems encountered with pipeline stability, solids settlement in the pipeline, blockages etc. due to faulty design or operating procedures, were investigated.

The final report on the project is due to be published early in 1989.

Research on the culturability of faecal coli following exposure to sea water — a pilot study

The CSIR commenced this pilot study during 1987 with the aim of determining the culturability rates of *Escherichia coli I* after



Funding of research on Marine Disposal expressed as a percentage of total WRC research expenditure (1981 to 1988).

various exposure times to sea water, by daylight, by night, in summer and in winter. The purpose of the study is to attempt to shed further light on the complex problem presented by the rapid decline of enteric microbial populations in the sea. The term "die-off" is commonly used in this context, but the term "disappearance" is probably more accurate.

Since water quality criteria for selected portions of the sea have been developed and limits for faecal coliforms have been specified in terms of these criteria, it is important to establish the fate of these indicator organisms in discharges to the sea. For the designer of a sea outfall sewer in particular, this information is of great importance since this one criterium will substantially influence the length of the outfall to ensure compliance with the quality criteria.

LIST OF RESEARCH PROJECTS

Current projects

- Research on marine disposal practice in South Africa (The CSIR — Division of Earth, Marine and Atmospheric Science and Technology).
- Research on the culturability of faecal coli following exposure to sea water — a pilot study (The CSIR — Division of Earth, Marine and Atmospheric Science and Technology).

Distribution of effluent discharged in the surf zone (Strand).

11 The treatment of industrial effluents

Industrial effluent is a major source of water pollution. Since the Water Act of 1956 requires that all effluents be purified and returned to the stream of origin, the quality rather than the quantity may become the most important factor in determining the availability of water for all uses in some areas. In view of South Africa's limited water resources, reclamation of effluent as a source of water will assume increasing importance, particularly in areas of urban and industrial development.

Research on industrial effluents is goal-orientated to provide significant savings on freshwater intake and a reduction in the total demand by recycling treated effluents. Purification systems are developed which produce water of the required quality suitable for a specific reuse purpose. In some areas the value of by-products, energy or raw materials recovered by the treatment of the effluents could cover a large part of and even exceed the cost of treatment.

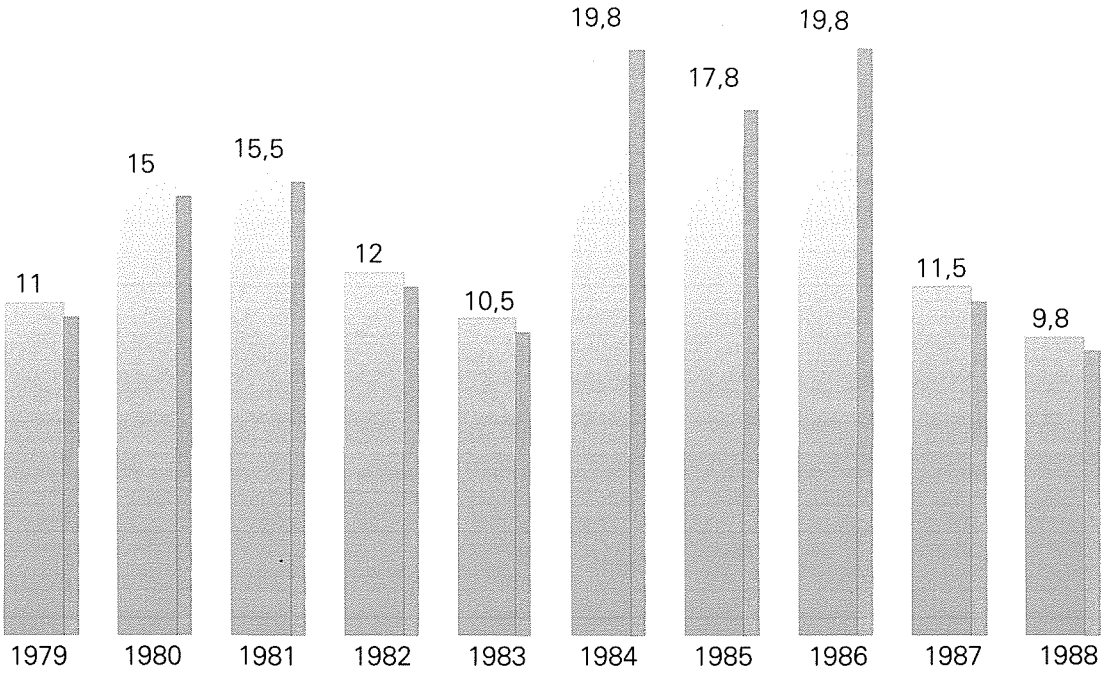
The Water Research Commission sponsored eight research projects on the treatment of industrial effluents during 1988, of which four commenced on 1 January 1988.

A REVIEW OF SOME CURRENT PROJECTS

A national industrial water and wastewater survey (NATSURV)

As part of an ongoing research program, the Water Research Commission in collaboration with the Department of Water Affairs initiated the NATSURV project in January 1984. The aims of the project are to establish a data base containing information on water intake, raw materials, products, effluent quality and quantity of industrial waste, and to identify areas where research is needed to assist factories in improving their water and effluent management at minimum cost.

The NATSURV project has two distinct modes of operation. The first of these is an industry specific survey of industries as identified by the project's technical subcommittee. Secondly an area survey is being carried out in the priority Vaal Barrage catchment area, covering all premises using more than 50 m^3/d of water for industrial purposes.



Funding of research on Industrial Effluents expressed as a percentage of total WRC research expenditure (1979 to 1988).

Results from the NATSURV industry survey are reported in the form of industry guides. These are written as short summaries of all the relevant information collected during the survey of a particular industry and are aimed at industries, legislators, researchers and local authorities.

The area survey of the Vaal Barrage catchment area is due for completion in December 1988 and is currently on schedule to achieve this objective. The total industrial water demand and pollution load for the catchment will be calculated and major industrial pollution point sources will be identified. This information should prove useful to the Department of Water Affairs in the management of water resources in the severely stressed PWV area.

Industry benefits from the NATSURV survey, through the development of a basic water and effluent management strategy for each of the premises visited. Often a NATSURV survey causes factory personnel to focus on water and effluent management for the first time and in doing so many factory managers have realised that improving water and effluent management is not necessarily a costly exercise and may in fact prove to be of financial benefit to the factory concerned.

Research into the treatment of wool scouring effluents

During 1988 a modular demonstration plant for the treatment of wool scouring effluents was commissioned at a South African wool scouring factory.

Dynamic membrane technology has been used for an ultrafiltration plant to process a desuinted wool scouring effluent with a water recovery of 85%. The permeate produced is suitable for reuse in the scouring process.

The operation of the plant is integrated with the wool washing process to a high degree and much of the plant operation is automated.

Incorporated in the operations of the plant is a continuous solids removal facility, which decreases the water usage.

Research on the development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents

During the course of this investigation it became obvious that the 'standard' method for the formation of dynamic membranes on stainless steel supports gave variable results. When the porous stainless steel tubes, of variable pore size, are pretreated by 'pore filling' with a suitable hydrous metal oxide, highly reproducible dynamic membranes can be formed by 'standard' procedures. Such membranes can then also be formed at low pressure (600 kPa) and operated at high pressure (6 000 kPa). In addition such membranes exhibit very high flux rates.

Further work on pore filling is necessary before true evaluation of special polymers is undertaken.

Routine analyses being carried out at the NATSURV laboratory.

Research on chemical removal of sulphates

The steadily increasing salt concentration in the Vaal River drainage system is a serious problem due to the large-scale recirculation of water, and the fact that conventional water treatment processes do not significantly reduce inorganic pollutants. Water pumped from four mines was found to contribute 38% of the salt load to the system, the major anion being sulphate, which results from the oxidation of pyrite. The removal of sulphates by precipitation with barium and the reclamation of the barium has been shown to be possible. The raw materials are coal and barium sulphate, both abundant in South Africa, and the products are water and sulphur, both in demand. The implementation of the process is being considered in conjunction with the mines and with Eskom and will decrease the total dissolved salts in the Vaal Barrage, benefitting all water consumers in the PWV area.

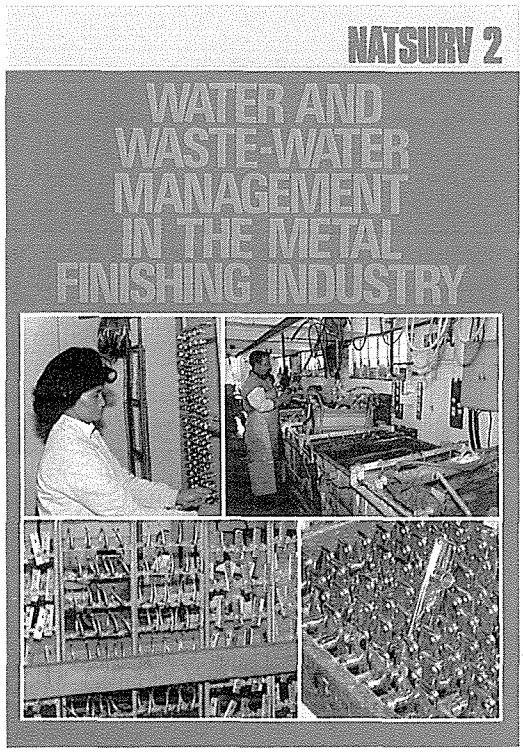
A DISCUSSION OF NEW PROJECTS

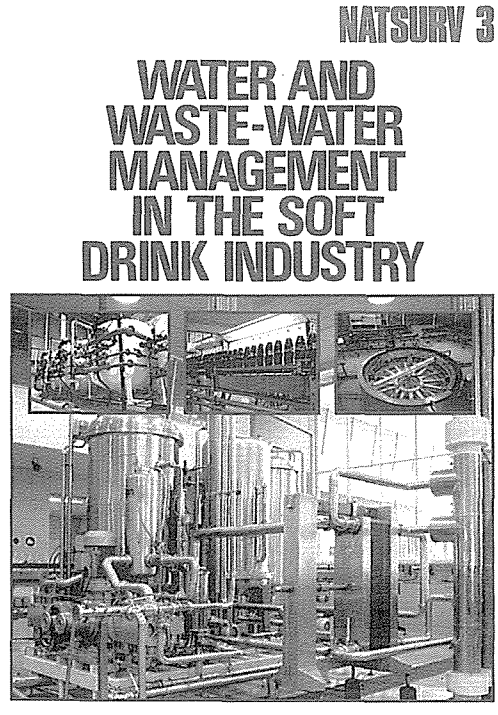
Research on design criteria for crossflow microfiltration

Because of the need for a more scientific understanding of crossflow microfiltration two particular studies have been undertaken. The first examines the fundamental transport mechanisms occurring inside a crossflow microfiltration tube and the second examines the design and optimisation of crossflow microfiltration systems as a whole. This project will run over a three-year period.

Transfer of waste-water management technology to the meat processing industry

This one-year project is aimed at providing the major representative of the red meat abattoir industry (the South African Abattoir Corporation) with a low-cost, low-risk opportunity of using, and assessing in





Two guides published as part of the NATSURV range.

their own environment, the membrane technology developed and evaluated in previous phases of the project by consulting engineers.

Membratek tubular membrane systems are being used to treat the screened and defatted effluent at a rate of about 40 m^3/d. The effluent is treated by ultrafiltration to separate recoverable organic material, while the filtrate from the first stage is reprocessed by cellulose acetate reverse osmosis to recover water for selected reuse in the abattoir.

Research on the removal of colloidal matter from stripliquor by coagulation and flocculation

Typical gas stripliquor, as found in coal gasification, was characterised with regard to size distribution and zeta potential of the colloidal material in the liquor. Most particles were of the order of 1 µm in diameter and were negatively charged. Cationic polymers and ferric salts were shown to be the most effective coagulation agents. Far less coagulant was required to produce filterable flocs than to produce settleable flocs. Pilot-scale investigations are being carried out at the moment to optimise flocculation. The duration of the project is fifteen months.

Research on solids-liquid separation in biological systems

An investigation into the application of crossflow microfiltration for solids-liquid separation in biological waste-water treatment systems is being undertaken over a one-year period. The objective of the project is not to optimise the filtration sytem, but rather to observe the impact of this mode of operation on the biological system. Results so far indicate that the biological mass can be increased without affecting the COD removal of the system. Increasing the biological mass in biological treatment systems such as anaerobic digestion or the activated sludge process can dramatically increase the performance of such systems, by reducing retention times and reactor capacities.

LIST OF RESEARCH PROJECTS

Current projects

- A national industrial water and waste-water survey (NATSURV) (The Department of Water Affairs, and a firm of consulting engineers: Steffen, Robertson and Kirsten Inc.).
- Research into the treatment of wool scouring effluents (The University of Natal — Department of Chemical Engineering; a firm of consulting engineers: Steffen, Robertson and Kirsten Inc.; and Gubb and Inggs (Pty) Ltd).
- Research on the development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents (The University of Natal — Department of Chemical Engineering; University of Stellenbosch; and the CSIR).
- Research on chemical removal of sulphates (The University of Natal — Department of Chemical Engineering).

New projects

- Research on design criteria for crossflow microfiltration (The University of Natal — Department of Chemical Engineering).
- Transfer of waste-water management technology to the meat processing industry (A firm of consulting engineers: Steffen, Robertson and Kirsten Inc.; and the South African Abattoir Corporation).
- Research on the removal of colloidal matter from gas stripliquor by coagulation and flocculation (The University of Pretoria — Department of Water Utilisation Engineering).
- Research on solids-liquid separation in biological systems (The University of Cape Town — Department of Chemical Engineering).

12 Water treatment and reclamation

The primary objective in supplying water for urban and industrial use is to provide every consumer with sufficient water of the required quality.

Regarding the quality of water it is imperative, firstly, to safeguard water sources against pollution, and secondly, to employ processes which are suitable for the treatment of water to the required quality. In this chapter an account is given of the development and application of treatment processes. One of the highlights of the year was the release of a computer program STASOFT which can be used for calculations in connection with the stabilisation, softening and mixing of different water types. The program was developed by Prof RE Loewenthal of the Department of Civil Engineering at the University of Cape Town, in terms of a contract with the Commission.

During the year a one-day workshop was held to determine problem areas in water treatment and to identify the research priorities which are required in order to overcome these problems. Several problems were identified and a document was compiled which summarises the problems and research needs.

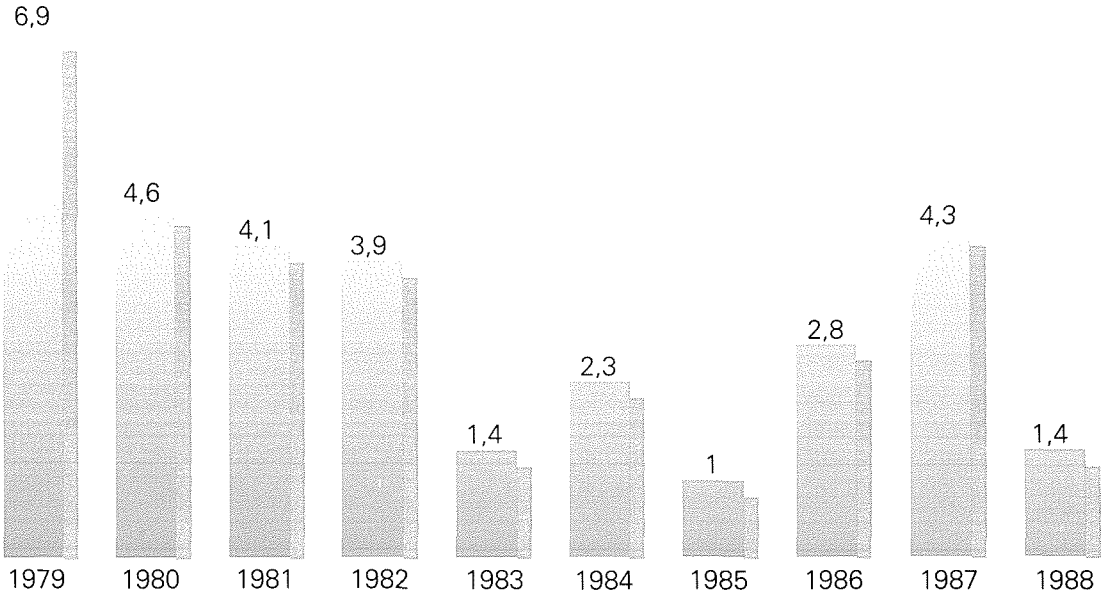
The WRC currently supports six projects in connection with the above, of which two commenced during the year.

A DISCUSSION OF NEW PROJECTS

A comparative study of chlorine dioxide and other oxidants in potable water treatment

The use of chlorine in potable water treatment can lead to problems, especially when treating water which is rich in algae. Although chlorine is a very effective disinfectant and oxidising agent, chlorinated compounds are formed when organic matter is present in the water. Some of these chlorinated compounds may be harmful and a study of alternative oxidants such as ozone and chlorine dioxide is therefore indicated.

The Western Transvaal Regional Water Company owns a full-scale ozone plant at the waterworks near Stilfontein, as well as a full-scale chlorine plant. This is an ideal arrangement for conducting comparative studies on alternative disinfectant technologies. A period was therefore initiated to compare the action of chlorine and ozone as well as chlorine dioxide on a comparative basis on pilot-scale. The two-year project is being carried out by the Western Transvaal Regional Water Company, the CSIR and the company Floccotan.



Funding of research on Water Treatment and Reuse expressed as a percentage of total WRC research expenditure (1979 to 1988).

Research on a combined flotation — powdered carbon process for potable water treatment

Flotation is a separation process which utilises the natural buoyancy of algae for removing them efficiently from algal-rich waters. Activated carbon is used to remove organic compounds from water, including compounds which cause odours and smells. These two processes can be combined for the treatment of water with a heavy growth of algae which occasionally causes smell and odour problems. The aim of this two-year project is to optimise the process.

LIST OF RESEARCH PROJECTS

Current projects

- Technological development of water reclamation on the basis of the Windhoek plant (The Municipality of Windhoek and the CSIR — Division of Water Technology).
- Research on dissolved air flotation for the treatment of eutrophied surface water for potable use (The CSIR — Division of Water Technology).
- An exploratory study into the efficiency of drinking-water treatment in South Africa (The University of Cape Town — Department of Civil Engineering).
- The construction and operation of the Cape Flats prototype water reclamation plant and surveillance of reclaimed water quality (The City Council of Cape Town).

New projects

- A comparative study of chlorine dioxide and other oxidants in potable water treatment (The CSIR, the Western Transvaal Regional Water Company, and Floccotan (Pty) Ltd).
- Research on a combined flotation — powdered carbon process for potable water treatment (The CSIR — Division of Water Technology).

13 Drinking-water quality and health aspects

The quality of drinking water has a direct influence on man's health, and therefore it should comply with specific norms before being utilised for human consumption. In South Africa there are no statutory criteria for drinking-water quality. The South African Bureau of Standards' specification *Water for Domestic Use* (SABS 24 —1984) is, however, accepted as a general guideline in this respect. Recently the Department of National Health and Community Development (the responsible authority for the creation of guidelines on quality) accepted new quality guidelines, which had been recommended by the CSIR, in principle. The guidelines provide for 56 aesthetic/physical and inorganic chemical determinants, which are 30 more than those covered by the SABS specification. Research on drinking-water quality therefore remains very important and the WRC supports several activities in this regard.

The overall objective of the WRC regarding this research is to gather information on all aspects of drinking-water quality and to develop a technology for water treatment, so that water which complies with quality criteria and possess no health risk, can be supplied to the consumer.

The following research objectives are emphasised:

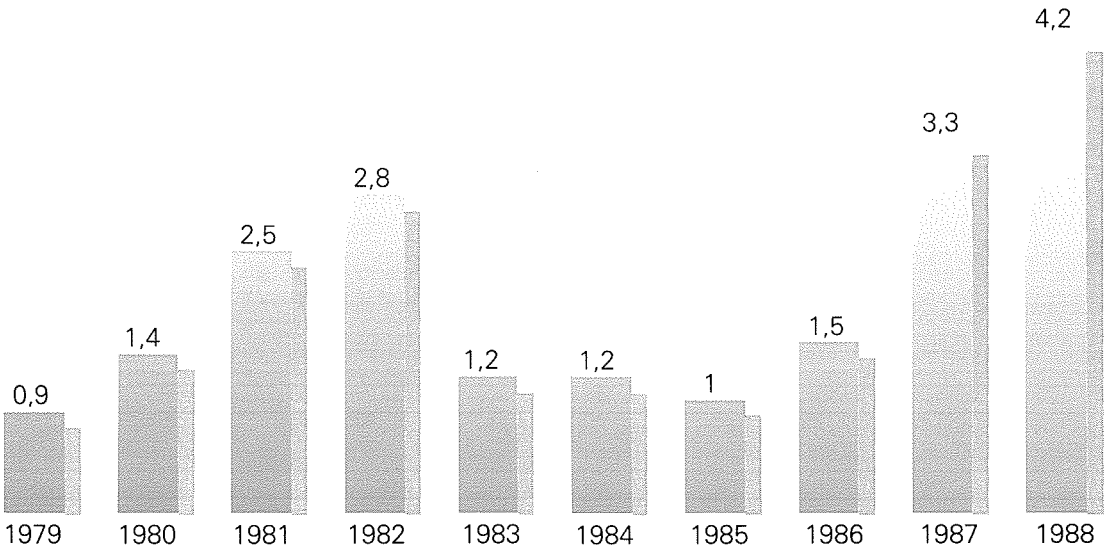
- development of the necessary water treatment technology (see **Chapter 12**);
- a study of the occurrence and concentration of contaminants (microbiological and chemical);
- the influence of water quality on man (*inter alia* epidemiological studies);
- obtaining data which can contribute to the formulation of quality criteria; and
- the importance of water quality in broader perspective (e.g. monitoring strategy and biocorrosion).

The WRC supported eight projects in connection with the above during the year. Of these one was completed and two commenced.

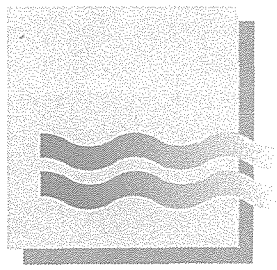
A REPORT ON A COMPLETED PROJECT

The development of a portable toxicity detector for water

The project aimed at developing a portable toxicity detector for water was completed during the year. The principle of the meter is based on the determination of the amount of light which is emitted by certain bioluminous compounds during a bioche-



Funding of research on Drinking-water Quality and Health Aspects expressed as a percentage of total WRC research expenditure (1979 to 1988).



mical reaction. The presence of toxic compounds has an inhibiting effect on the enzyme system, resulting in decreased light emission. This decrease is then associated with the presence of toxic compounds in the water. The CSIR, which carried out the research, investigated a new concept for determining light emission, viz. the use of modern solid-state electronic technology.

The commercialisation of the detector is being investigated by the CSIR.

A REVIEW OF SOME CURRENT PROJECTS

The research on the occurrence and concentration of trihalomethanes in drinking-water has been completed and the final report is being prepared. Trihalomethanes are halogenated organic compounds which are formed as a result of the disinfection of water with chlorine. These compounds are of interest because of their potential health risk to the consumer.

During the year good progress has been made with research on the development of monitoring strategies for water quality and procedures for the interpretation of water quality data. Dr Jane Harris of the Colorado State University, Fort Collins, USA, is the project leader in South Africa and a research and development team and a consumer group have been formed. The development of the project was further stimulated through inputs made by Profs Thomas Sanders and Robert Ward, also from Colorado State University, in the course of discussions during their visit to South Africa.

The study which is being conducted in Windhoek by the SAIMR on the possible health effects of reclaimed water on the consumer has been in progress since 1976 and is coming to an end this year.

A report was published during 1987 detailing the findings of a 10-year study on behalf of the Water Research Commission into various health aspects of human consumption of reclaimed water in Windhoek, Namibia. Adverse effects in the form of some common bacterial and viral intestinal infections were not demonstrated and this aspect of the study was therefore terminated. The mortality studies were continued and funded for two years by the SAIMR pending the possibility of a new contract with the WRC which was entered into with effect from April 1986 to enable the continuation of these studies for a further three years.

A detailed report covering the entire 12-year mortality study from August 1976 to December 1988 will be issued during the second quarter of 1989.

Studies are continuing on the epidemiological surveillance of potential changes in water quality with the collection, comparison and analysis of South African health data. Mortality data are being analysed at a national level as well as by geographic region and by occupation.

A national birth defect surveillance system has been established in conjunction with the Genetic Services Division of the Department of National Health and Population Development.

A DISCUSSION OF NEW PROJECTS

Research on the assessment of water quality problems due to microbial growth in drinking-water distribution systems

Despite adequate disinfection at the point of distribution it can happen that certain micro-organisms collect in the distribution system by forming biofilms. Several factors in the distribution systems contribute to this aftergrowth and biofilm formation.

This microbial growth can include several different types of micro-organisms. There are *inter alia* those which constitute health implications, those which cause bad odours and taste and those which cause biocorrosion. It also appears that these organisms develop a resistance to biocides.

In terms of an agreement the CSIR will do research over a period of two years on the nature and extent of problems pertaining to water quality related to biofilms. Recommendations will be made on further research which can be done to counter these problems.

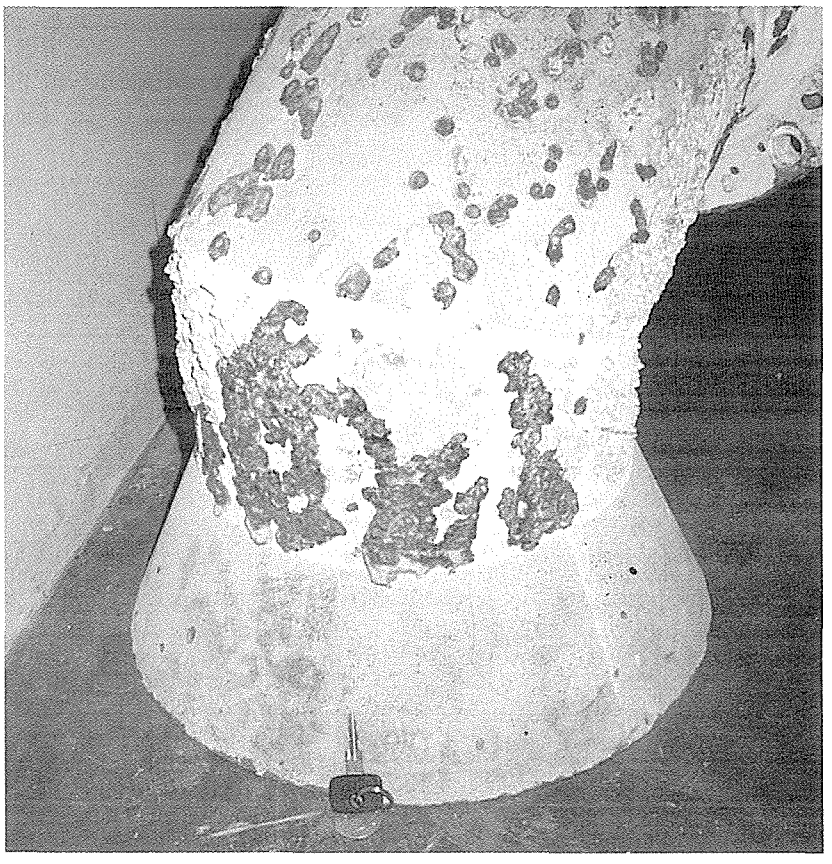
Research on the effect of biocorrosion in water systems

Biocorrosion is caused by the action of micro-organisms, such as bacteria, which attack material (in *inter alia* water pipelines, cooling towers, boilers, etc.) thus causing degeneration.

Biocorrosion is the cause of big problems for the South African industry. Not only does material have to be replaced from time to time, but large amounts of chemical substances (biocides) have to be employed for the control of biological action.

This three-year project which will be carried out by the CSIR in terms of an agreement with the Commission, will establish the nature and extent of the micro-organisms, especially the sulphate-reducing bacteria which are found in certain systems. The effect of biocides on the bacteria will also be investigated. The eventual objective of the research is to obtain information which can make a contribution towards the prevention and control of biocorrosion.

A typical example of biocorrosion on a pipe immersed in water.



LIST OF RESEARCH PROJECTS

Completed project

- The development of a portable toxicity detector for water (CSIR — Division of Water Technology).

Current projects

- An investigation into the occurrence and concentration of trihalomethanes and their precursors in South African drinking water (CSIR — Division of Water Technology).
- Research on the isolation and identification of mutagens in drinking water (CSIR — Division of Water Technology).
- Development of water quality monitoring strategies and procedures for water quality data interpretation (CSIR — Division of Water Technology and the Department of Water Affairs).
- Research on epidemiological surveillance of potential changes in drinking-water quality (The University of Cape Town — Department of Community Health).
- Research on the possible chronic health effects of consumption of reclaimed water by consumers in Windhoek (The South African Institute for Medical Research).

New projects

- Research on the assessment of water quality problems due to microbial growth in drinking-water distribution systems (CSIR — Division of Water Technology).
- Research on the effect of biocorrosion in water systems (CSIR — Division of Water Technology).

14 Desalination

Desalination of water is aimed at two different facets, viz.:

- Production of drinking water from sea or brackish water. This can be achieved through distillation, reverse osmosis or electrodialysis and comprises a reduction in the dissolved inorganic salt concentration of approximately 500 mg/ℓ in the water.
- Removal of dissolved salts from effluents in order to combat pollution of the water environment and drinking-water sources. This can be attained by means of distillation, electrodialysis or chemical precipitation.

Over the last ten years a good deal of research has been done on the first aspect, i.e. the production of drinking water. The processes are therefore well-known and no further research on these is being supported by the Commission.

The removal of dissolved salts from effluents is, however, still somewhat problematic, as the characteristics of the effluents can vary over a wide spectrum. This causes problems because the membranes can be damaged or clogged and scaling or corrosion can take place in distillation plants. The Commission therefore supports a number of projects on the desalination of different types of effluents and mine waters.

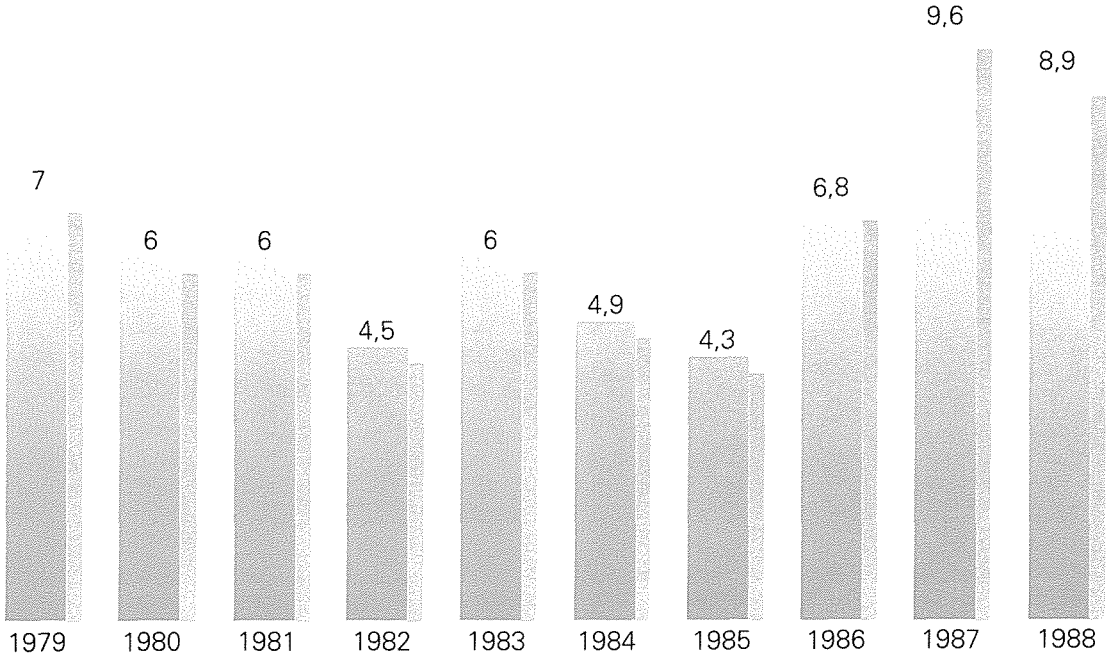
During August a three-day workshop on desalination and membrane processes was held in order to identify problem areas and research needs and to effect information transfer. During the workshop a southern African Desalination and Membrane Interest Group was established to disseminate information on the processes and applications thereof and to enhance the communication between researchers, the suppliers of equipment and the users of the technology.

A DISCUSSION OF NEW PROJECTS

Three new projects commenced during 1988.

The development of seeded reverse osmosis technology

This three-year project in terms of an agreement between the Commission, the Chamber of Mines, Iscor and Bintech (Pty) Ltd is aimed at developing the technology for the desalination of water which gives rise to calcium sulphate scaling. The process is based on the principle that precipitation will rather take place on seed crystals than on membranes, should such seed crystals be present. A slurry of very fine crystals is therefore circulated in a tubular reverse osmosis system to prevent scale formation and to enhance desalination.



Funding of research on Desalination expressed as a percentage of total WRC research expenditure (1979 to 1988).

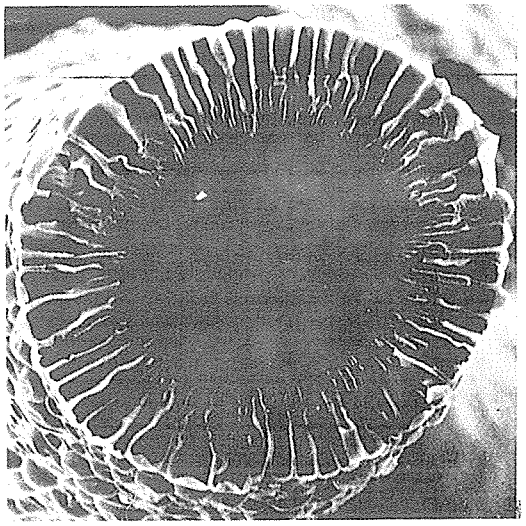
Research on the concentration of industrial effluents with sealed-cell electrodialysis

This project will be carried out over a period of two years by the CSIR. The process is based on the usual electrodialysis principle but utilises a simple sealed cell to remove salts from solutions and to concentrate these to high concentrations.

The development of a low-cost ultrafiltration module

This one-year project, in terms of an agreement with Bintech (Pty) Ltd, was initiated in view of the development of local technology to solve specific problems.

Ultrafiltration is one of a group of pressure-driven membrane processes, including reverse osmosis and microfiltration. Ultrafiltration membranes are less dense than reverse osmosis membranes and therefore cannot remove ions, although dissolved and colloidal organic compounds, including bacteria and viruses, can be removed. The process is therefore very suitable for the production of high quality water, for the purification of effluents which contain organic material (e.g. in the food industry) and also for other special applications, *inter alia* for the clarification of fruit juices and cordials.



Cross section of a capillary ultrafiltration membrane.

The technology for the manufacture of ultrafiltration membranes had been developed previously in terms of an agreement with the Commission. The objective of this new project is to develop a low-cost module, making use of tubular ultrafiltration membranes.

The overall aim of this project is to release low-cost ultrafiltration units in South Africa for the cost-effective purification of specific effluents, for the production of high quality water and for other applications.

LIST OF RESEARCH PROJECTS

Current projects

- Pilot plant studies on the desalination of underground mine water with EDR (The Chamber of Mines).
- Research on membrane development and fabrication for reverse osmosis and ultrafiltration (The University of Stellenbosch — Institute for Polymer Science).
- Research on the feasibility of reverse osmosis for water reclamation on large scale (The Municipality of Port Elizabeth, the CSIR and Bintech (Pty) Ltd).
- Research on the treatment of inorganic brines (The University of Natal — Department of Chemical Engineering).
- The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents (The University of Stellenbosch — Institute for Polymer Science).

New projects

- The development of seeded reverse osmosis technology (Chamber of Mines, Iscor and Bintech (Pty) Ltd).
- Research on the concentration of industrial effluents with sealed-cell electrodialysis (CSIR — Division of Water Technology).
- The development of a low-cost ultrafiltration module (Bintech (Pty) Ltd).

15 Rural and urban water supply

With increasing water demand in South Africa the years of plenty which separate the years of restrictions will become fewer while the periods of restrictions will lengthen accordingly. The large interbasin transfer schemes currently under construction can cope with the demand for the next 20 to 25 years, but notwithstanding the return of normal rainfall patterns, continued research into water economy in the urban sector is essential to promote economy and ensure future supplies.

REPORT ON A COMPLETED PROJECT

Research into water consumption and possible water saving in apartment buildings

Twin blocks of flats were used in this project. One block was retrofitted with water meters while the other was monitored as a control.

Results indicated that by metering individual consumers in apartment buildings, approximately 25 per cent of the total consumption could be saved. It is also possible to identify the consumers who exceed the average quota for the building. The existence of a leak on the premises could also easily be detected when the sum of the individual meters was compared with the bulk water meter reading.

The project team has strongly recommended that the water supply system to all new communal developments should be designed with a view to the fitting of water meters either at the outset or at a later stage, should the respective local authority so require.

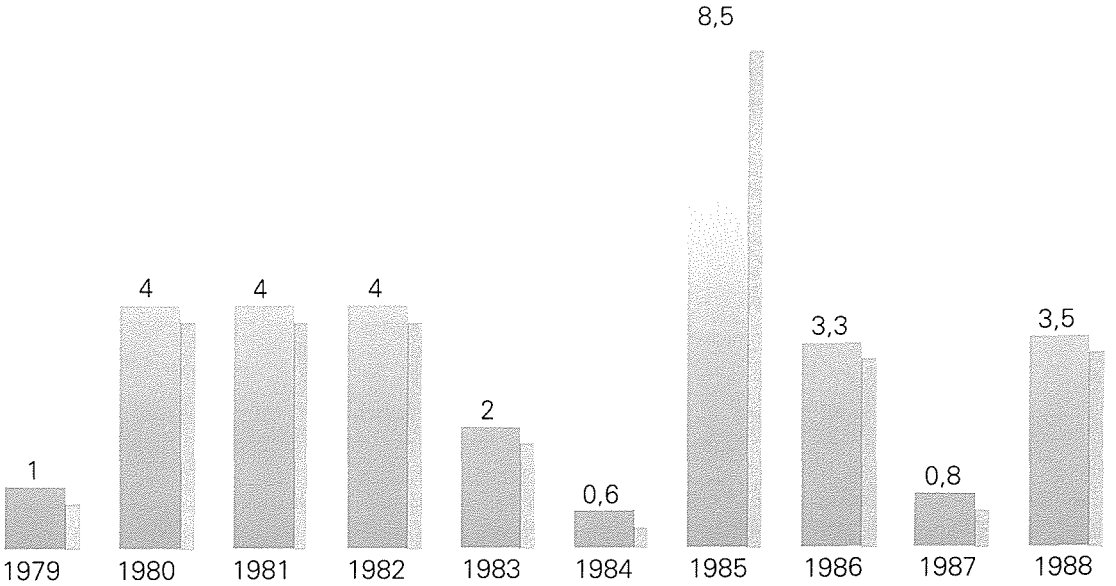
A DISCUSSION OF NEW PROJECTS

During the year three new projects commenced.

Research on the development and testing of data-logging equipment for the monitoring of water consumption patterns

The collection and recording of data pertaining to domestic water use are of the utmost importance to water engineers of local authorities. As only expensive imported equipment was available with the necessary high resolution required, the CSIR entered into a two-year agreement with the WRC to develop a suitable data logger locally.

Initially progress with the development of the equipment was unacceptably slow as the Pretoria City Council urgently needed data loggers for use on an existing project with the University of Pretoria investigating unaccounted-for water in municipal



Funding of research on Water Supply in Rural and Urban Areas expressed as a percentage of total WRC research expenditure (1979 to 1988).

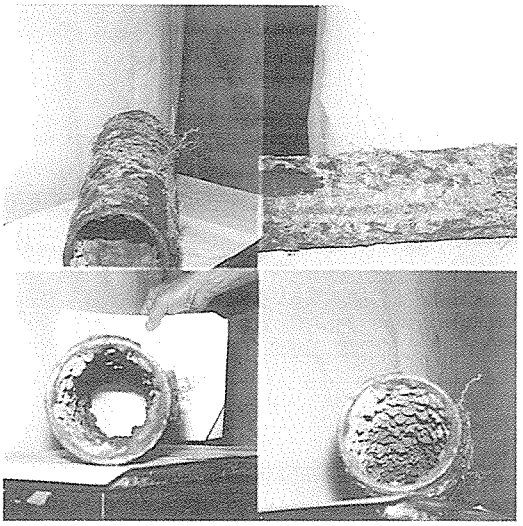
water supply systems. These problems have, however, been overcome and a prototype data logger is currently operating satisfactorily.

Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas.

The South African industry as well as the steel pipelines used by local authorities in the water supply network are severely affected by corrosion annually.

The corrosive attack from the outside of the pipes is of much greater magnitude than the corrosive attack from the water inside the pipes. For this reason external corrosion has received most attention thus far. In terms of a three-year agreement, the CSIR will research internal corrosion. The aims of the project are to evaluate the corrosion characteristics of water introduced from areas beyond the Vaal River catchment and the effects of various blends of these waters on the performance of pipes in the PWV/Klerksdorp regions. Water chemistry and the related corrosion prediction indices and diagrams will be compared with actual corrosion studies using these blended waters.

The results obtained from these investigations will be used to provide the necessary technology for predicting the likely performance of pipe materials.



An example of corrosion in pipelines.

As the water authority supplying the bulk of the water to the regions, the Rand Water Board is closely involved in a consultative capacity and has made sample collection and laboratory facilities available to the project team.

Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects

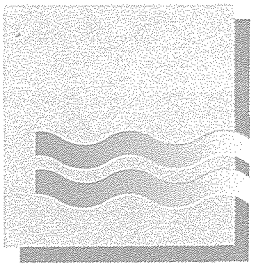
The CSIR has entered into a two-year agreement with the Commission to develop practical guidelines on how to optimise the cost-effectiveness of rural water supply and sanitation programmes in southern Africa, particularly in low-income rural areas.

The main objectives of the project are:

- to conduct surveys of the needs and resources of selected rural communities; the expertise and experience of rural development organisations; and the requirements of the organisations which are sources of development funds;
- to investigate methods to optimise the cost-effectiveness of rural development programmes and to evaluate projects;
- to develop practical guidelines for assessing cost-effectiveness and evaluating the success of projects; and
- to institute a system for regular review and improvement of the guidelines and for marketing them to the potential users.

The upgrading of water supply and sanitation facilities is a necessary part of the development of low-income rural communities if the basic needs of these people are to be met. Reasonable access to at least 20 ℓ of safe drinking water per person daily, as stated by the World Health Organisation, is the absolute minimum requirement. Sanitation facilities should be hygienic and should comply with the cultural requirements of the particular communities.

Organisations, both government and non-government, are involved in rural development. Despite the fact that sufficient technology exists for the construction of rural water supply and sanitation facilities, implementation of these schemes is fraught



with difficulties that are peculiar to the third world environment. Countless examples have been cited of well-planned schemes which have failed, simply because insufficient attention was given to factors that apply in the third world environment.

The guidelines that will be the end product of these investigations are not intended to prescribe to the organisations involved with rural development, but to provide a basis for objective evaluation and improvement and by so doing to contribute to the overall development of rural areas in southern Africa.

LIST OF RESEARCH PROJECTS

Completed project

- Research on water consumption and possible water savings in apartment buildings (The CSIR — Division of Building Technology).

Current projects

- Research on the effects of reduced water consumption on domestic sewer systems (The CSIR — Division of Building Technology).
- Research on ground-water abstraction in residential areas (The CSIR — Division of Building Technology).
- Research on the flow rate and pattern of water consumption and unaccounted-for water in urban areas (The University of Pretoria — Department of Civil Engineering and the City Council of Pretoria).
- Research into water loss analysis on municipal water distribution systems (Castle Brass Holdings (Pty) Ltd and the Johannesburg City Council).

New projects

- Research on the development and testing of data-logging equipment for the monitoring of water consumption patterns (The CSIR — Division of Building Technology).
- Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas (The CSIR — Division of Material Science and Technology).
- Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects (The CSIR — Division of Water Technology).

16 Water economy at power stations

Water is indispensable to power generation and therefore the latter is one of the strategic industries with the highest priority for an assured water supply. At a power station water is mainly used for steam generation to drive the turbines and for cooling the condensers. The cooling water itself becomes hot in the cooling process and must therefore be cooled down before reuse. Cooling takes place as a result of evaporation of part of the water in the well-known concrete cooling towers at power stations.

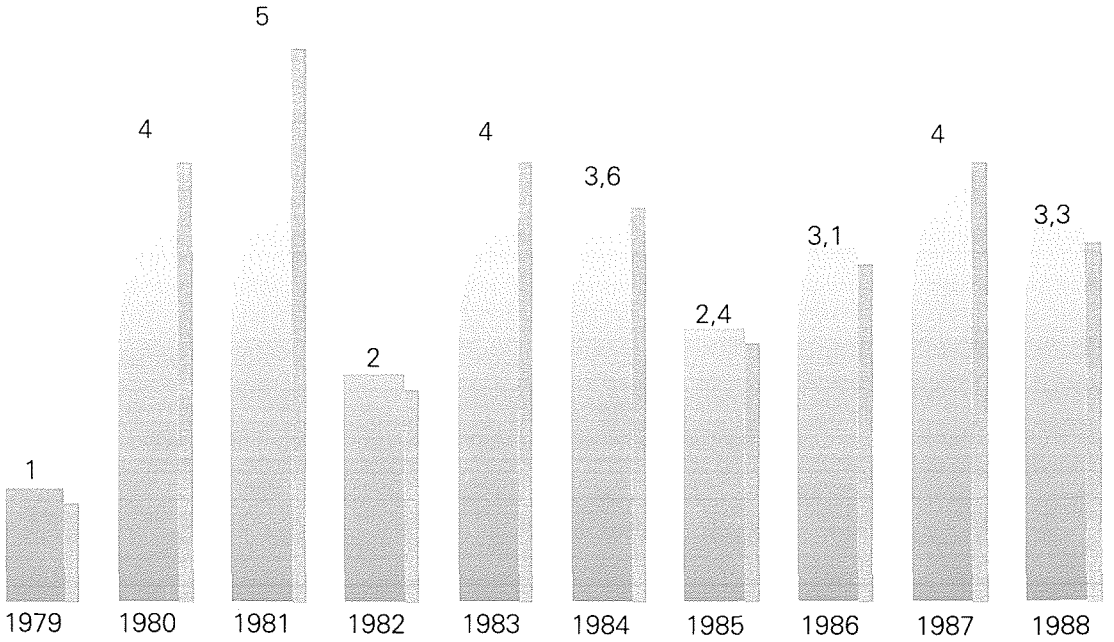
These evaporation losses can be almost completely eliminated by implementing dry cooling. No evaporation takes place in a dry-cooling system as the hot water runs in pipes and is air-cooled, as in the radiator of a motor car.

Although these systems effect considerable water savings, certain disadvantages are associated with the process. Firstly the capital investment for dry cooling greatly exceeds that for wet cooling and secondly, dry cooling is less efficient, necessitating the use of more coal for the same amount of energy generation than with wet cooling. It is therefore necessary that dry-cooling systems should be made to operate as efficiently as possible.

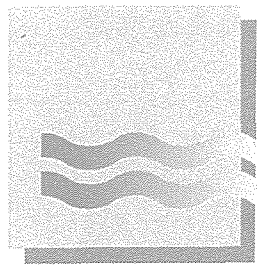
During the 1970's it became apparent that the provision of adequate water for additionally planned power stations on the Transvaal coal-fields would become difficult. Eskom was therefore confronted with the fact that some of its power stations would have to be dry-cooled and, furthermore, that it would have to be done on a scale which had not been done elsewhere and for which only limited experience was available. In discussions with Eskom and the Department of Water Affairs, the Commission undertook to support research in collaboration with Eskom on the optimisation of dry and dry-wet cooling under local conditions.

The Commission has been supporting research on the following aspects since 1979:

- the effect of atmospheric conditions on the performance of dry-cooling towers;
- the development of computer techniques for the evaluation and optimisation of dry-wet cooling systems;
- research on the possible recirculation of hot air in dry-cooling systems; and
- research on corrosion in dry and dry-wet cooling tubes.



Funding of research on Water Economy at Power Stations expressed as a percentage of total WRC research expenditure (1979 to 1988).



Three of the new generation air-cooled power stations are presently under construction. Matimba near Ellisras in the Transvaal, which employs a direct air-cooled condensing system, is the most advanced, and two of its six 600 MW systems have already been commissioned.

The first systems at the Kendal Power Station will become operational in 1988/89. This power station employs an indirect cooling system through which cooling water is air-cooled in dry-cooling towers. The third power station, Majuba, near Volksrust, is still at an early stage of construction and will be unique in that three of the units will be dry-cooled (similar to Matimba) and the other three units will make use of conventional wet cooling.

DISCUSSION OF A NEW PROJECT

Model studies on the minimisation of hot air recirculation of dry and dry-wet cooling systems

This two-year project between the WRC, the CSIR and Eskom is a continuation of model studies on dry and dry-wet cooling which have been carried out by the CSIR over the past two years. The studies are aimed at quantifying the hot air circulation which can occur under particular circumstances at the new dry and dry-wet cooled power stations and to formulate guidelines on the minimisation of the effects.

The model studies are being carried out in a water tunnel at the CSIR. The objective of the new project is to extend these studies to include power stations which make use of a combination of dry and wet cooling systems.

LIST OF RESEARCH PROJECTS

Current projects

- Research on thermal feedback caused by dry cooling at power generating stations (Eskom and the CSIR — Division of Earth, Marine and Atmospheric Science and Technology).
- Model studies on air flow patterns in mechanical draught air cooling systems at power stations (Eskom and the CSIR — Division of Earth, Marine and Atmospheric Science and Technology).
- Computer and laboratory optimisation studies on dry and dry-wet cooling (Eskom and the University of Stellenbosch — Bureau of Mechanical Engineering).

New project

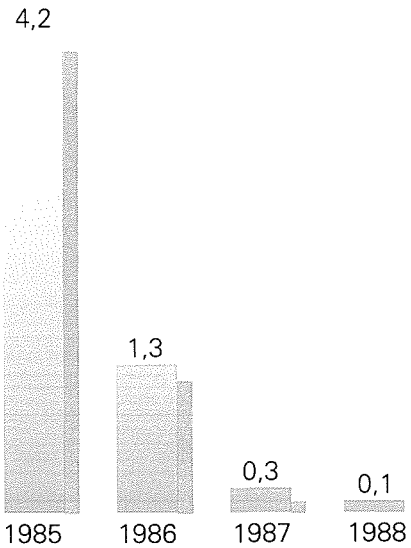
- Model studies on the minimisation of hot air recirculation of dry and dry-wet cooling systems (Eskom and the CSIR — Division of Aeronautical Systems Technology).

17 Socio-economic effects of water restrictions

As a result of the water restrictions imposed since 1985 on various sectors and water supply systems of the RSA, the WRC entered into agreements with three research organisations to investigate the nature and extent of the socio-economic and financial consequences of water restrictions. Water restrictions are and will remain one of the most important measures for conserving water during times of restricted water supplies. Little is however known of the nature and magnitude of the consequences of such restrictions — neither locally nor overseas. The approach is that the quality of life may not be lowered to an unacceptable level by water restrictions but the information necessary for the optimal management of water supply under these circumstances is sadly lacking. This situation therefore formed the background to the three projects launched in 1985 in this regard.

The sectors investigated and the organisations responsible for each of the sectors, are the following:

- Irrigation farming, mining, electricity supply and the central government: Institute for Social and Economic Research, University of the OFS (UOFS).
- Households: Bureau for Market Research, University of South Africa (UNISA).
- Local authorities, industries and trade: Centre for Applied Social Services, University of Natal.



Funding of research on Socio-economic Effects of Water Restrictions expressed as a percentage of total WRC research expenditure (1985 to 1988).

The research was done for five water supply systems, as well as for the head offices of Eskom and certain authorities and other institutions. The period of water restrictions for each of the supply systems was as follows:

- Ngagane River Government Water Scheme, Natal: 18 March 1983 to 23 March 1984.
- Umgeni catchment area, Natal: 18 March 1983 to 22 June 1984.
- Riet River Government Water Scheme, OFS: 1 March 1984 to 31 March 1985.
- Vaalharts Government Water Scheme, Cape Province: 1 March 1984 to 31 March 1985.
- Vaal River system, excluding tributaries of the Vaal River: 18 March 1983 to 31 March 1985 for households, business and service sectors and local authorities, and 1 March 1984 to 31 March 1985 for agriculture, mining and government institutions.
- Eskom: 18 March 1983 to 31 March 1984.

Upon interpretation of the results contained in the reports of the UOFS and UNISA, it should be noted that the periods for which the impact of water restrictions was assessed, differ for the various water supply systems. The restrictions in Natal were for example already lifted in June 1984, while for the rest of the areas under investigation they were lifted only at the beginning of October 1987. This situation therefore prevents unqualified comparisons being made between supply systems, and it also means that the magnitude of the full impact of the water restrictions is in actual fact larger than was indicated in already-published reports. Since the above-mentioned investigations covered only the period 18 March 1983 to 31 March 1985, negotiations are presently under way also to investigate the period 31 March 1985 to 30 September 1987.

The accompanying table sets out the total net tangible effect of the water restrictions for each sector and for each of the areas under investigation. As can be expected, the economic impact was the largest for households of the Vaal River System, viz. R255,5 × 10^6. A large portion of this amount (about 70%) is the result of

expenses which are in actual fact improvements to the relevant properties, e.g. supply of own water by means of boreholes; paving and the installation of more effective garden irrigation systems, but this represents expenses which would otherwise not have been incurred. It is furthermore also clear that the densely populated areas, as well as the intensive agricultural areas, were affected most severely by the water restrictions. The negative figures which appear in the table, in other words positive economic consequences, are attributable to higher income derived from fines imposed for illegal water consumption and from increased water tariffs, but are in fact expenses for the water user.

With regard to the non-tangible consequences a distinction was made in the case of households between the impact on customs and on the quality of life. Customs affected in urban households were also affected among farmers, but differed in intensity. Differences also became apparent between water supply systems. Customs and components of the quality of life were for example affected more severely at the Ngagane River Government Water Scheme than at the Vaal River System. In general irrigation of gardens was the custom affected relatively most, while the practice of sport and recreation was influenced relatively less. An aspect of the quality of life which was influenced to a major degree was the appearance of gardens, but the utilisation of swimming-pools was not severely affected.

LIST OF RESEARCH PROJECTS

Completed project

- Research on the socio-economic effects of water restrictions on irrigation farming, mining, electricity supply and the central authority (The University of the OFS — Institute for Social and Economic Research).

Current project

- Research on the socio-economic effects of water restrictions on industries and local governments (The University of Natal — Centre for Applied Social Studies).

TABLE: Total net tangible effect of water restrictions per sector for each of the areas investigated, 18 March 1983 to 31 March 1985 (in R × 10^6)

SECTOR	NGAGANE GWS*	UMGENI CATCH-MENT	RIET-RIVER GWS*	VAAL-HARTS GWS*	VAAL RIVER SYSTEM	HEAD OFFICE
House-holds	1,4	5,1	—	—	255,5	—
Business & Services	2,9	63,9	—	—	122,1	—
Eskom	—	—	—	—	—	72,8
Agriculture	0,2	2,8	10,4	32,4	20,3	—
Mining	0,9	—	—	—	44,8	—
Govern-ment authori-ties	4,3	9,3	3,1	0,5	−3,2	7,2
Local authorities	2,6	−3,6	—	—	10,6	—
TOTAL	12,3	77,5	13,5	32,9	450,1	80,0

*GWS = Government Water Scheme

18 Research support services

The mission of the Water Research Commission is to promote water research in South Africa. This entails the co-ordination, stimulation and encouragement of research on all aspects of water. To fulfil this mission, it is essential to provide information systems to aid the planning and execution of research.

The WRC has developed a number of such information systems as research support services. These operate on two levels, firstly on a primary level, which serves all of water research, and secondly on a secondary level which serves only one or other aspect of water research.

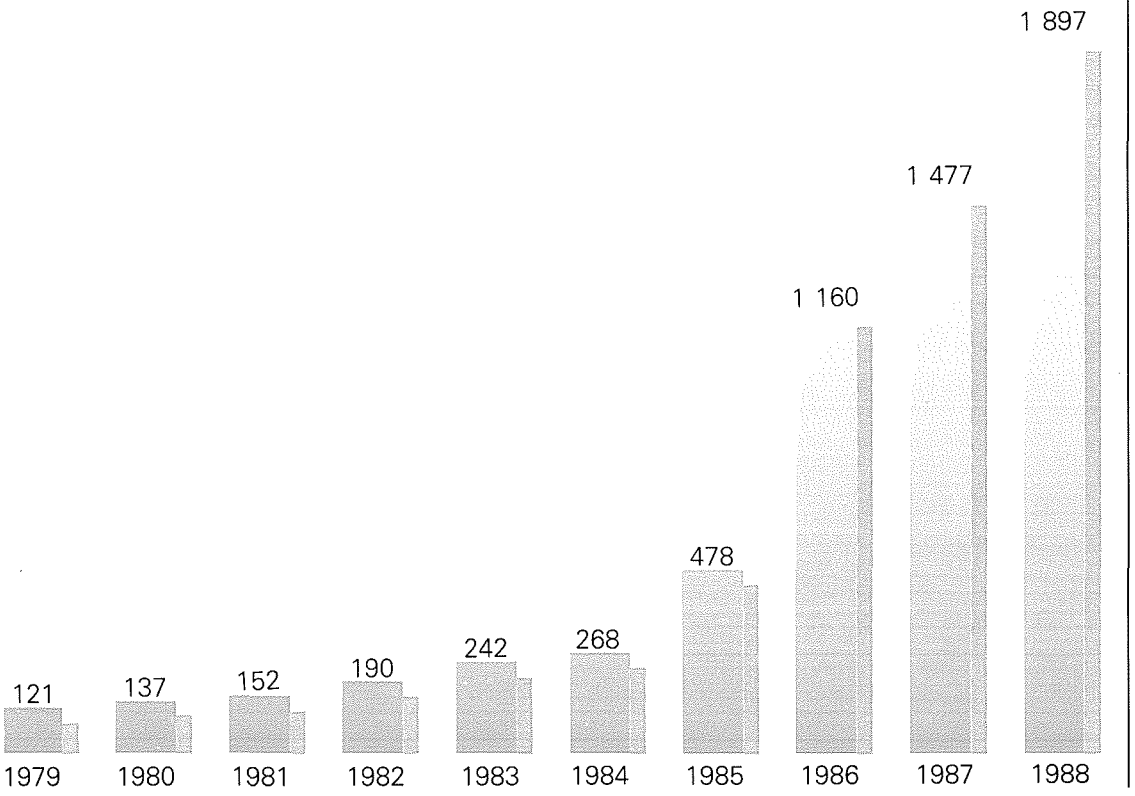
THE COMPUTING CENTRE FOR WATER RESEARCH (CCWR)

In 1986, the WRC in collaboration with ISM (Pty) Ltd (then still IBM (SA) (Pty) Ltd) and the University of Natal, established the Computing Centre for Water Research (CCWR) which is a numeric information system. The mission of the CCWR is:
"To support water research in South Africa by providing a national, computer-based information system which will:

- enhance the transfer of data and results;
- provide a facility for multi-disciplinary research; and
- provide alternative computer facilities."

The objectives of the CCWR are:

1. The provision of a national facility for:
   - the enhanced transfer of data and other information between supply organisations and researchers;
   - the development of appropriate data products and the provision of these to researchers;
   - the provision of appropriate applications software for water research purposes; and
   - the enhanced transfer of research results between researchers and end-user organisations.
2. The provision of a facility whereby multi-disciplinary, multi-organisational research can be undertaken by people in different organisations throughout the country.
3. The provision of enhanced and/or alternative computing and computer graphics capabilities for water researchers throughout South Africa.



Funding of Research Support Services by the WRC for 1979 to 1988 (in 10^3 Rand).

During 1987 the CCWR expanded its services by providing full graphics capability to remote centres using SAPONET. Users at the Universities of Rhodes, Natal and the Orange Free State now have synchronous access to the CCWR.

The CCWR is now accessible through DIGINET connection to the Universities of the Orange Free State and Rhodes and through CSIRNET to the Universities of Stellenbosch and Cape Town. In addition, the CCWR has joined UNINET which is a joint computing network among certain research councils, universities and other organisations. Researchers from the Universities of the Witwatersrand, Potchefstroom and Pretoria, as well as the CSIR are able to access the CCWR through UNINET. Dial-in access to the CCWR is possible from anywhere in the RSA.

The CCWR has 78 registered users at 16 institutions. A wide variety of water research topics are being addressed and collaborative research ventures have been initiated between centres. The technology-transfer function of the CCWR is developing fast and to date several hundred requests for research information products have been serviced.

THE SOUTH AFRICAN WATER INFORMATION CENTRE (SAWIC)

The SAWIC is funded by the WRC and is operated by the Centre for Information Services of the CSIR. The SAWIC provides services on a national basis to all users who require information on water-related topics.

The SAWIC operates a computerised bibliographic data base WATERLIT, which has been developed by themselves. WATERLIT presently contains over 142 000 references which are added to at a rate of 10 500 items per year. Items are selected from 439 scientific and technical journals, as well as reports, theses, books and conference proceedings.

In the course of the year an average of 139 retrospective information searches were carried out monthly on WATERLIT. Some of these retrospective searches were done by the Department of Water Affairs, other divisions and regional offices of the CSIR, university libraries and the JLB Smith Institute of Ichthyology.

Approximately 370 clients made use of the SDI (selective dissemination of information) service in which they are informed monthly of publications in their specific field of interest.

The SAWIC has continued to provide support to the JLB Smith Institute of Ichthyology in Grahamstown to develop the data base FISHLIT. This data base contains over 12 000 references on fish and at present about 128 SDI profiles are run on a monthly basis. SAWIC has free access to FISHLIT.

The 1988 edition of the *Bibliography of African Limnology South of the Sahara* was compiled by SAWIC for the Limnological Society of South Africa.

The publication *Selected Journals on Water (SJOW)* contains the title pages of 57 core journals in various water-related fields. During 1988 175 subscribers received this monthly publication.

Table 1 contains information on the users of WATERLIT for 1987 and 1988, and **Table 2** contains information on the most frequently requested topics for 1988.

THE HYDROLOGICAL INFORMATION SYSTEM (HIS)

Hydrological research in South Africa stands to benefit greatly from the much improved accessibility of data which will result from the development of an efficient computerised national information system called the Hydrological Information System (HIS). This project, which is being undertaken by the Department of Water Affairs with the assistance of the WRC, consists primarily of two concurrent phases, namely a data bank development phase and a data preparation and loading phase. The data bank development phase is already well advanced, all indications being that it will have reached completion by the time the five-year contract period terminates at the end of 1990.

Provision has been made for the inclusion of *inter alia* river flow, reservoir, sediment,

Table 1: Use of the SAWIC's services by various sectors

	1987	1988
Total	1 316	1 668
	%	%
Private sector	28,04	33,97
Educational institutions	27,20	20,29
Government and semi-state organisations	19,05	21,91
CSIR	12,90	16,47
Miscellaneous	10,48	2,65
Foreign	2,33	4,71

Table 2: Most frequently requested topics

Total	**1 668**
	%
Waste water and effluents	16,0
Water treatment	11,0
Hydrology	8,0
Limnology	6,7
Pollution	6,5
Industrial wastes	6,0
Aquaculture	6,0
Irrigation and agriculture	4,5
Health	4,2
Water distribution and QC	4,1
Appropriate technology	3,0
Water supply	2,7
Dams	2,4
Solid wastes and composting	2,0
Corrosion	2,0
Industrial water	2,0
Ground water	2,0
Fish biology	1,6
Analytical techniques	1,5
Mariculture	1,0
Marine pollution	1,0
Hydraulics engineering	1,0
Freshwater fish	1,0
Desalination	0,8
Estuaries	0,7
Erosion	0,6
Marine biology	0,6
Remote sensing	0,5
Aquatic weed control	0,4
Safety	0,2

water quality, evaporation and groundwater data. Although the phase consisting of preparation and loading of historic data is expected to take longer, it is nevertheless expected that by the end of 1990 the greater and most useful proportion of the data will have been dealt with. Much effort is at present going into the digitisation of recorder charts, the software for which has recently been upgraded for increased production.

LIST OF SUPPORT SERVICES

- The establishment of a National Hydrological Information System (HIS) (The Department of Water Affairs).
- South African Water Information Centre (SAWIC) (CSIR — Centre for Information Services).
- Computing Centre for Water Research (CCWR) (The University of Natal and ISM (Pty) Ltd).

19 The transfer of information and technology

The promotion of information and technology transfer is one of the most important objectives of the Commission. This is very clearly defined in the Water Research Act, namely to "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

For the promotion of its programme of information and technology transfer, the Commission has developed a number of activities. Although some of these activities are directed at the transfer of information, the emphasis falls mainly on technology transfer, i.e. the application of research results, since this will always represent the final dividend of the research investment. Frequently references are made in various chapters of the annual report to specific actions taken in the interest of technology transfer. These actions are not described in any detail in this chapter, but reference is made to the methods used for the promotion of technology transfer.

PARTNERSHIP RESEARCH

Partnership research is regarded as a very effective method of enhancing technology tranfer. The partnership principle is incorporated, as far as possible, in research projects, and means that the end user of the results participates in the planning and execution of the research.

PUBLICATIONS

The Commission's publications cater for three levels, viz. pure scientific, popular scientific and practical scientific.

Water SA

Water SA is the Commission's scientific journal which contains original research articles and review articles on all aspects of water science, technology and engineering. The journal appears quarterly and the first edition was launched in April 1975.

Water SA has a strict refereeing system whereby all articles submitted for publication are first referred to referees, whereafter a decision is taken on publication.

Water SA has an extensive local as well as overseas readership. It also enjoys worldwide coverage in the sense that it is covered by more than 20 international abstracting services who publish and distribute summaries of articles which appear in *Water SA*.

SA Waterbulletin

SA Waterbulletin is a bilingual bi-monthly periodical. Within the broad spectrum of water research it aims to:

- furnish information on water and water research in a popular scientific manner to the different interest groups in the water field;
- promote the transfer of technology by announcing the availability of reports, manuals, guides etc. which emanate from water research;
- promote communication between the Water Research Commission and authorities and individuals, such as researchers, engineers, technicians, government departments, local authorities and the industrial and agricultural sectors; and
- convey social news and matters of interest (e.g. about conferences and personalities) to the water research community.

MANUALS, GUIDELINES AND REPORTS

At the conclusion of a project, and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof. More information on these publications appears in the relevant chapters in the Annexure.

LIST OF COMMISSION PUBLICATIONS

The Annexure to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1988 and which emanated from research supported wholly or in part by the Commission.

CONFERENCES, SEMINARS, WORKSHOPS AND DEMONSTRATIONS

From time to time the Commission, on its own or in co-operation with other organisations, arranges such meetings. These afford ideal opportunities for promoting personal contact between research scientists or between research scientists and the users of research results. In this way the transfer of information and technology is greatly enhanced. More information on meetings held during the year is contained in the individual chapters.

MASS MEDIA

In this regard the accent falls on information transfer, and press releases, radio and television are used to this end.

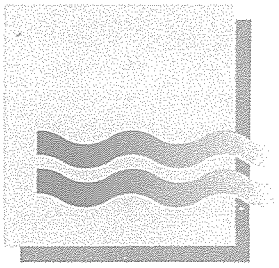
UTILISATION OF OVERSEAS EXPERTISE

It is in the national interest that overseas expertise and knowledge be used where these are not available locally, and the Commission has developed various methods to achieve this. Overseas specialists, for example, are engaged as consultants and the Commission from time to time sends personnel and other experts overseas in order to obtain information on a particular problem area. More information in this regard appears in the individual chapters.

COMMERCIALISATION

In the future the WRC will focus increasingly on a further aspect of technology transfer, which is in progress already, viz. the commercialisation of research results by e.g. the private sector. The patenting of research results and the sale of publications and computer programs would be classified as such. In this way the WRC earns royalties, locally as well as abroad.

20 Financial statements



The Statement of Income and Expenditure and the Balance Sheet have been drawn up in terms of section 14(2) of the Water Research Act, 1971 (Act No. 34 of 1971), as amended and certified by the Auditor-General and cover the period 1 January 1987 to 31 December 1987.

The Commission derives its income from rates and charges on water usage and on scheduled irrigation land. The tariffs for the 1988 financial year were 0,90c/m^3 for water supplied for urban, industrial or domestic use, and 100c/ha of land scheduled for irrigation.

WATER RESEARCH COMMISSION
STATEMENT 1
BALANCE SHEET AS AT 31 DECEMBER 1987

1986	Liabilities	1987	
R		R	R
	Accumulated Funds –		
	Balance at 31/12/86	12 436 378,63	
12 436 379	*Plus:* Income over expenditure, 1987	5 304 580,43	17 740 959,06
	Current liabilities –		
	Sundry creditors –		
	Revenue paid in advance	4 435,31	
31 551	Bank overdraft	996,87	5 432,18
R12 467 930			R17 746 391,24

1986	Assets		1987	
R		R	R	R
	*Capital assets –			
5 000	Land (Cost)		5 000,00	
	Motor vehicles	28 703,30		
27 830	*Less:* Depreciation	4 753,46	23 949,84	
	Office equipment	249 224,23		
219 002	*Less:* Depreciation	11 489,54	237 734,69	
	Office furniture	32 875,20		
30 920	*Less:* Depreciation	1 587,22	31 287,98	297 972,51
7 233 222	Loan			9 226 921,52
	Investments		4 928 441,82	
2 285 719	*Plus:* Accrued interest		108 315,80	5 036 757,62
	Current assets –			
	Sundry debtors –			
975 337	Outstanding revenue		875 895,70	
214 107	In transit		–	
1 286 315	Project advances (Statement 3)	2 220 776,35		
919	Subsistence and transport advances	–		
122 120	*Motor financing*	87 617,54		
300	Deposits	300,00	2 308 693,89	
150	Cash on hand		150,00	
66 989	Cash in bank		–	3 184 739,59
R12 467 930				R17 746 391,24

*Capital assets purchased by organisations by means of research grants are not included.

Pretoria, 7 April 1988

(Signed) P.E. Odendaal
Executive Director

The above Balance Sheet has been audited in accordance with the provisions of section 42(4) of the Exchequer and Audit Act, No. 66 of 1975, read with section 14(1) of the Water Research Act, No. 34 of 1971, and in my opinion reflects a true and fair view of the financial affairs of the Water Research Commission.

Cape Town, 21 April 1988

(Signed) J.H. de Loor
Auditor-General

WATER RESEARCH COMMISSION

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1987

1986	Expenditure	1987
R		R
1 710 435	Salaries and allowances	1 848 060,02
6 946	Motor transport	10 403,52
46 716	Subsistence	48 231,77
161 700	General transport	195 949,04
1 800	Commission members' allowances	1 700,00
9 083	Postal and telegraph services	11 412,72
40 448	Telephone services	43 750,55
34 759	Printing and stationery	39 139,87
3 160	Advertisements	17 114,34
226 419	Publications and information	258 482,43
8 393	Technology and information transfer	14 105,24
25 878	Lease and maintenance of office equipment	37 824,15
8 675	Entertainment	10 213,48
58 262	Office rental	71 064,80
1 114	Maintenance of and alterations to offices	1 089,35
6 573	Electricity	9 412,52
208	Maintenance and lease of furniture	33,15
3 807	Typing and translation services	1 154,13
7 618	Insurance and licenses	18 536,27
119 197	Collection fees	159 042,84
1 847	Audit fees	3 845,53
6 448	Legal costs	128 640,26
27 348	Registrations and subscriptions	24 330,08
9 443	Miscellaneous petty expenses	15 276,60
16 488	Depreciation	17 830,22
8 877 902	Research projects and Research Support Services (Statement 3)	7 246 076,86
187 938	Contracting of researchers and expertise	221 502,69
110 000	Research and other grants	105 000,00
68 054	Specialist and consultation services	110 336,49
311 812	Income over expenditure	5 304 580,43
R12 098 471		R15 974 139,35

1986	Income		1987
R		R	R
	Rates		
	Government irrigation schemes with canal systems:		
	Received	163 715,18	
157 429	*Plus:* Outstanding	35 103,35	198 818,53
	Irrigation Board Schemes:		
	Received	183 222,87	
150 987	*Plus:* Outstanding	106 980,89	290 203,76
	Charges		
	Metered water from Government schemes:		
	Received	11 530 865,57	
9 483 021	*Plus:* Outstanding	585 664,50	12 116 530,07
	Municipalities:		
	Received	2 854 372,99	
2 023 088	*Plus:* Outstanding	146 081,63	3 000 454,62
	Interest on rates and charges in arrear		
	Received	7 464,90	
4 373	*Plus:* Outstanding	2 065,33	9 530,23
	Interest on investments:		
	Received	162 325,15	
240 326	Accrued	108 315,80	270 640,95
39 247	Sundry income		87 961,19
R12 098 471			R15 974 139,35

WATER RESEARCH COMMISSION

STATEMENT 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1987

Project	Expenditure		Total advances outstanding as at 31/12/87
	1987	Total to 31/12/87	
1. RESEARCH PROJECTS	R	R	R
Technological development of water reclamation on the basis of the Windhoek plant	4 148,46	810 965,55	*(516,94)
The construction and operation of the Cape Flats prototype water reclamation plant and the surveillance of reclaimed water quality	23 809,00	931 395,62	81 613,52
Research on the influence of different times and intensities of internal plant moisture stress on photosynthesis, respiration and water use efficiency of certain agronomic crops	45 100,00	377 431,80	–
Development of the required apparatus and programmes for the monitoring and management of irrigation systems	294,98	522 063,42	–
Research on the revision of the temporal and spatial distribution of precipitation statistics in Southern Africa	39 374,18	278 151,41	–
Research on urban hydrology and drainage	56 250,00	361 850,70	–
A detailed regional soil moisture deficit analysis for irrigation planning in Southern Africa	10 350,00	65 327,51	–
Research on detailed geohydrological investigations in the Poesjenels River catchment in the Breede River valley, with special reference to mineralization	21 301,57	223 515,13	*(9 301,57)
Water management and effluent treatment in the textile industry: Treatment of scouring and bleaching effluent	40 230,69	733 850,25	7 769,31
Research on an investigation into the use of physical/chemical techniques for water and wastewater management in the meat processing industry	–	500 600,00	60 100,00
Research on the inhibition of bacterial oxidation of pyrite and the concomitant acid mine drainage	16 957,51	152 170,98	1 914,02
An investigation into the condition of soils irrigated over a protracted period and an evaluation of applicable selection criteria, and reclamation and control measures	6 391,48	55 711,32	6 117,68
Research on the contribution of mine dumps to mineral pollution in the Vaal Barrage	84 376,84	233 900,00	–
Research on enhancement of biological phosphate removal from sewage by altering process feed composition	17 156,87	221 635,17	8 507,11
Hydrological research in catchments of the Eastern and Southern Cape	153 514,38	468 427,79	*(3 647,79)
Research on an evaluation of hydrological flood estimation techniques for small ungauged catchments	15 000,00	210 056,32	–
Research on the use of soil/root conductance index and stress ratio as inputs for the determination of irrigation requirements of selected soil/plant/atmosphere systems	60 612,23	270 416,60	6 896,64
A national industrial water and wastewater survey	–	1 871 188,12	547 800,00
Research on biological foam in the activated sludge process	15 831,84	67 051,74	–
Research on biological excess phosphate removal	–	426 243,41	139 828,95
An investigation into rainfall recharge to groundwater	–	456 598,80	121 268,71
Research on the development of a national data bank for groundwater data	204 150,42	706 999,95	–
Research on correction factors for the evaporimeter coëfficients used in the irrigation scheduling of wheat	49 027,82	202 512,95	7 172,18
Research on the practical scheduling of irrigation in the Northern Transvaal	121 192,38	227 156,41	*(22 796,29)
Research on the quantification and limitation of water losses associated with centre pivot irrigation systems	63 165,61	169 720,49	*(2 165,61)
Applied hydrological process and modelling studies for the determination of water and sediment yield	210 347,89	735 199,59	40 800,41
Research on design stormflow and peak discharge rates for small catchments in Southern Africa	46 102,50	208 221,45	–
Research into water loss analysis on municipal water distribution systems	142 285,00	450 900,00	–
Research on thermal feedback caused by dry cooling at power generating stations	38 000,00	155 928,00	*(5 796,00)
Research on the evaluation and optimisation of full-scale chemical phosphate removal in biological sewage treatment processes	56 275,87	143 033,86	*(572,91)
Research into the treatment of wool scouring effluents	69 495,59	757 973,22	211 246,78
The technical performance evaluation of a full-scale industrial wastewater treatment plant: Textile dyehouse effluent treatment by hyperfiltration and evaporation	–	44 162,72	2 412,28
The development of support systems for cross-flow microfiltration and technical performance evaluation on industrial waters and wastewaters	132 300,00	422 110,26	*(200,26)
Research on and development and full-scale evaluation of preventative and remedial methods for the control of activated sludge bulking	20 985,46	113 202,39	57 653,76
Research on improving irrigation management based on soil water monitoring and detailed knowledge of profile available water capacities	102 977,22	148 700,17	75 999,83
Research on the sosio-economic effects of water restrictions on industries and local governments	70 152,24	98 234,63	*(12 776,97)
Research on the exploitation potential of Karoo aquifers	195 127,08	548 754,40	24 175,64
Research on membrane development and fabrication for reverse osmosis and ultrafiltration	549 845,09	1 222 410,30	35 154,91
Research on the health implications of the intake of chemical contaminants by man	4 857,12	14 457,89	–
The development of management-orientated models for eutrophication control	53 872,00	182 458,00	20 401,00
Modelling of the groundwater quality in the Atlantis aquifer	244 139,37	408 176,79	71 860,21
The development of a computer program to simulate water flow in distribution canals	63 485,83	88 583,07	17 708,91
Research into water consumption and possible water saving in apartment buildings	7 307,09	39 600,00	*(1 100,00)

STATEMENT 3 (continued)

Project	Expenditure		Total advances outstanding as at 31/12/87
	1987	Total to 31/12/87	
	R	R	R
Research on the possible chronic health effects of consumption of reclaimed water on the consumer at Windhoek	22 278,00	38 229,67	*(1 978,00)
Pilot plant studies on the desalination of underground mine water with EDR	1 906,58	15 000,00	–
Research on chemical characterisation of South African municipal sludge	22 927,00	36 554,00	1 073,00
Research on the evaluation of the impact of the phosphate standard on the water quality and trophic status of Hartbeespoort Dam	85 219,00	150 293,00	*(3 593,00)
Research on the effective use of water by means of an algal-aqua culture system	14 355,88	22 444,11	*(355,88)
Research on the effects of urbanisation on catchment water balance	162 348,74	162 348,74	230 001,26
A pilot study of the irrigated areas served by the Breede River (Robertson) irrigation canal	89 407,20	194 953,27	–
Research on drip irrigation of tomatoes	202 062,13	202 062,13	100 037,87
Research on epidemiological surveillance of potential changes in drinking water quality	–	97 491,68	113 234,40
Research on the development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents	202 231,60	386 503,41	4 916,59
Research on the evaluation and optimisation of the process of dual digestion of sewage sludge	113 402,04	160 256,04	11 943,96
Model studies on air flow patterns in mechanical draught air cooling systems at power stations	40 000,00	75 000,00	–
Computer and laboratory optimization studies on dry and dry-wet cooling	332 733,31	516 796,69	*(29 733,31)
Research on the feasibility of reverse osmosis for water reclamation on large scale	266 606,00	516 606,00	19 394,00
The development of a portable toxicity detector for water	17 872,00	17 872,00	22 128,00
An investigation into the occurrence and concentration of trihalomethanes and their precursors in South African drinking water	32 438,00	33 832,00	6 268,00
Hydrosalinity studies in the Eastern Cape	362 394,19	362 394,19	48 965,81
Research on the evaluation of the abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone	67 740,78	108 912,65	16 387,35
Development of phosphate export models for catchments	3 574,00	8 376,00	1 424,00
The development of methods to assess the impact of agricultural practices on water resources in Southern Africa	122 748,72	122 748,72	18 751,28
Research on the effects of reduced water consumption on domestic sewer systems	21 764,96	21 764,96	*(1 764,96)
Research on the development of a stochastic daily climate model for South African conditions	–	–	40 890,15
Research on the treatment of inorganic brines and concentrates	107 524,83	107 524,83	*(424,83)
Research on dissolved air flotation for the treatment of eutrophied surface water for potable use	51 871,00	51 871,00	*(2 991,00)
Research on chemical removal of sulphates	32 931,06	32 931,06	*(2 231,06)
Development of water quality monitoring strategies and procedures for water quality data interpretation	49 537,00	49 537,00	*(11 537,00)
Research on the isolation and identification of mutagens in drinking water	37 008,00	37 008,00	*(17 508,00)
Research into water consumption rates and patterns and unaccounted-for water in urban areas	–	–	18 000,00
Research on the development of an adjustable low pressure flow-rate control valve for flood irrigation	–	–	25 000,00
Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils	20 998,96	20 998,96	2 501,04
An investigation into methods of developing operational rules for individual irrigation systems	131 183,09	131 183,09	29 466,91
Research on electro-chemical produced metal coagulants for the treatment of polluted water	–	–	6 500,00
Research on groundwater abstraction in residential areas	26 901,10	26 901,10	3 098,90
Research on the use of electromagnetic exploration techniques for the development of groundwater resources	–	–	50 000,00
Research of marine disposal practice in South Africa	17 247,60	17 247,60	2 752,40
Research on the culturability of faecal coli following exposure to seawater – a pilot study	–	–	5 000,00
Research on phosphate crystallization in activated sludge systems	15 563,00	15 563,00	34 437,00
Research on the evaluation and development of techniques for the determination of geo-hydrological parameters by use of geo-electrical methods	11 144,00	11 144,00	1 356,00
Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State	27 144,60	27 144,60	5 025,40
TOTAL	5 768 855,98	20 106 541,68	2 233 963,79
2. RESEARCH SUPPORT SERVICES			
South African Water Information Centre	338 428,06	920 987,37	*(80 794,76)
The establishment of a national hydrological information system	956 400,14	1 738 637,84	–
Establishment of a computing centre for water research	182 392,68	290 743,58	67 607,32
TOTAL	1 477 220,88	2 950 368,79	*(13 187,44)
GRAND TOTAL	7 246 076,86	23 056 910,47	2 220 776,35

*Excess expenditure over advances for projects.

WATER RESEARCH COMMISSION
STATEMENT 4
Budget 1989

	R	R
ESTIMATED INCOME		
Rates and charges in terms of Section 11 of the Water Research Act		21 903 000
Interest on investment		100 000
Sundry income		240 000
Loan		1 000 000
TOTAL ESTIMATED INCOME		R23 243 000
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries and allowances	2 684 000	
Subsistence and travelling expenses	338 000	
Postal, telegraph and telephone	71 000	
Printing, stationery, advertisements and publications	545 000	
General expenditure	749 400	
	4 387 400	
Interest on loan: Erf sewe-nul-ses Rietfontein (Pty) Ltd	280 000	4 667 400
Research expenses:		
Research projects:		
Technological development of water reclamation on the basis of the Windhoek plant	16 000	
Research on the inhibition of bacterial oxidation of pyrite and the concomitant acid mine drainage	22 400	
A national industrial water and wastewater survey	550 700	
Research on correction factors for the evaporimeter coefficients used in the irrigation scheduling of wheat	14 000	
Research on the practical scheduling of irrigation in the Northern Transvaal	56 400	
Research on the quantification and limitation of water losses associated with centre pivot irrigation systems	64 000	
Applied hydrological process and modelling studies for the determination of water and sediment yield	166 000	
Research on thermal feedback caused by dry cooling at power generating stations	84 000	
Research into the treatment of wool scouring effluents	60 500	
Research on improving irrigation management based on soil water monitoring and detailed knowledge of profile available water capacities	7 000	
Research on the exploitation potential of Karoo aquifers	15 228	
The development of management-orientated models for eutrophication control	14 600	
The development of a computer program to simulate water flow in distribution canals	500	
Research on the evaluation of the impact of the phosphate standard on the water quality and trophic status of Hartbeespoort Dam	15 000	
Research on the effects of urbanisation on catchment water balance	245 000	
Research on drip irrigation of tomatoes	130 000	
Research on epidemiological surveillance of potential changes in drinking water quality	40 000	
Research on the development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents	27 952	
Research on the evaluation and optimisation of the process of dual digestion of sewage sludge	166 800	
Research on the feasability of reverse osmosis for water reclamation on large scale	110 000	
Hydrosalinity studies in the Eastern Cape	215 200	
Research on the evaluation of the abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone	88 800	
Development of phosphate export models for catchments	94 700	
The development of methods to assess the impact of agricultural practices on water resources in Southern Africa	252 200	
Research on the effects of reduced water consumption on domestic sewer systems	24 850	
Research on the development of a stochastic daily climate model for South African conditions	75 500	
Research on the treatment of inorganic brines and concentrates	241 000	
Development of water quality monitoring strategies and procedures for water quality data interpretation	86 000	
Research on the isolation and identification of mutagens in drinking water	54 233	
Research into flowrates and patterns of water consumption as well as unaccounted for water in urban areas	36 195	
Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils	110 000	
An investigation into methods of developing operational rules for individual irrigation systems	143 700	
Research on groundwater abstraction in residential areas	90 510	
Research on the use of electromagnetic exploration techniques for the development of ground-water resources	92 000	
Research on phosphate crystallization in activated sludge systems	30 000	
Research on the evaluation and development of techniques for the determination of geohydrological parameters by use of geoelectrical methods	23 000	
Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State region	92 200	
The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents	628 000	
Research on geohydrological investigation and evaluation of the Zululand coastal aquifer	170 000	
Research on the reconstruction of the climatic history of the last 2000 years in the summer rainfall regions of Southern Africa	41 000	
Research on precipitation and airflow in cumulus clouds	212 500	

STATEMENT 4 (continued)

Research on the development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State Gold Fields	338 000	
Research on the enhancement of the national ground-water data base facilities	151 000	
Research on maximizing irrigation project efficiency in different soil-climate-irrigation situations	165 000	
Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi-arid regions	183 550	
Research on the factors affecting the water use efficiency of irrigated crops, with special reference to the physiological responses of these crops	257 000	
Research on the estimation and evaporation of moisture stress in crops by means of remote control aerial surveillance	59 300	
Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects	170 000	
An investigation of the hydrological response to third world settlements in peri-urban areas of Natal/KwaZulu	12 000	
The development of a systems model for the Mgeni catchment	120 300	
Hydrological modelling studies in the Eastern Cape	461 400	
The development of a model to simulate flow in alluvial rivers	79 200	
Research on the quantification of the effects of land use on run-off quality in selected catchments in Natal	75 400	
Research on the design criteria for cross-flow microfiltration	226 000	
Transfer of waste water treatment management technology to the meat processing industry	46 000	
Research on the filtration of compressible cakes	47 000	
Research on solids-liquid separation in biological systems	20 000	
Research on a combined flotation-powdered carbon process for potable water treatment	7 000	
The development of seeded reverse osmosis technology	100 000	
Research on the concentration of industrial effluents with sealed-cell electrodialysis	45 000	
A comparative study on chlorine dioxide and other oxidants in potable water treatment	40 000	
Research on chemical augmentation of biological phosphate removal	24 000	
Research on pelletisation in upflow anaerobic sludge bed (UASB) systems	86 000	
Research on phosphate fixation in waste waters by means of controlled struvite formation	60 000	
Consolidation of activated sludge and water chemistry research	57 000	
Research on the assessment of water quality problems due to microbial growth in drinking water distribution systems	115 000	
Research on the effect of biocorrosion in water systems	50 000	
Research on the effects of varying water quality on the corrosion of different pipe materials on the PWVS/ Klerksdorp areas	99 900	
Research on the development and testing of data logging equipment for the monitoring of water consumption patterns	66 900	
Research on the evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses	219 100	
Research on water use efficiency of certain irrigated temperate pasture species	124 800	
Model studies on the minimization of hot air recirculation of dry- and dry-wet cooling systems	100 000	
Expected projects	4 439 500	
	12 653 018	
Contracting of researchers and expertise	60 000	
Research and other grants	180 000	
Specialist and Consultation Services	210 000	
Loan (Company for Research on Atmospheric Water Supply)	2 681 000	
Research Support Services	2 086 215	17 870 233
TOTAL ESTIMATED EXPENDITURE		22 537 633
Expected investment balance		705 367
		R23 243 000

WATER RESEARCH COMMISSION

STATEMENT 5

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31 DECEMBER 1988

Payments	1988	
	R	R
Salaries and allowances		2 009 481,93
Motor transport		6 588,38
Motor vehicles		140 696,00
Subsistence		53 825,37
Subsistence and transport advances		38 752,88
General transport		207 482,76
Commission members' allowances		5 678,66
Postal and telegraph services		17 317,16
Telephone services		40 030,23
Printing and stationery		42 226,57
Advertisements		36 275,00
Publications and information		314 100,80
Technology and information transfer		16 764,71
Office equipment		24 893,66
Lease and maintenance of office equipment		47 158,45
Entertainment		13 228,27
Office rental		164 362,34
Maintenance of and alterations to offices		8 720,00
Electricity		15 077,54
Office furniture		103 344,84
Maintenance and lease of furniture		3 712,22
Typing and translation services		10 015,63
Insurance and licenses		18 100,93
Collection fees		188 330,28
Audit fees		3 378,08
Legal costs		67 077,96
Registrations and subscriptions		33 740,52
Miscellaneous petty expenses		36 566,83
Deposits		300,00
Project advances		6 936 461,18
Research projects		228 921,35
Contracting of researchers and expertise		257 231,59
Research and other grants		107 000,00
Specialist and consultation services		113 826,38
Loans		2 658 472,66
Acquisition of Erf Sewe-nul-ses Rietfontein (Pty) Ltd		4 500 000,00
Research support services		1 140 730,88
Balance as at 31 December 1988 –		
Investment at Corporation for Public deposits	4 655 517,55	
Cash on hand	150,00	
Cash in bank	16 595,47	4 672 263,02
		R24 282 135,06

Receipts	1988	
	R	R
Balance on 1 January 1988 –		
Investment at Corporation for Public deposits	4 928 441,82	
Cash on hand	150,00	
	4 928 591,82	
Less: Bank overdraft	996,87	4 927 594,95
Rates –		
Government irrigation schemes with canal systems		194 524,02
Irrigation Board Schemes		200 990,79
Charges –		
Metered water from Government schemes		14 402 893,65
Municipalities		4 018 940,61
Interest on rates and charges in arrear		15 680,69
Interest on investments		327 075,73
Sundry income		194 434,62
		R24 282 135,06

Annexure

PUBLICATIONS EMANATING FROM RESEARCH FINANCED WHOLLY OR PARTIALLY BY THE COMMISSION

This appendix contains a list of publications released in 1988. Requests for publications should be directed, as far as possible, to the authors.

PUBLICATIONS FOR 1988
ARTICLES AND PAPERS

Bennie, ATP en Burger, R du T (1988) Penetration resistance of fine sandy soils as affected by relative bulk density, water contact and texture. *S. Afr. J. Plant Sci.* **5** 5-10.

Bennie, ATP en Van Antwerpen, R (1988) An evaluation of empirical root growth models to describe root distribution in compacted soils. Paper presented at the 11th Congress of the Inst. Soil Tillage Res., Edinburgh, Scotland.

Bindoff, AM, Treffry-Goatley, K, Fortmann, NE, Hunt, JW en Buckley, CA (1988) The application of cross-flow microfiltration technology to the concentration of sewage works sludge streams. *Journal of the Institution of Water and Environmental Management* **2** (5) 513-522.

Bindoff, AM, Treffry-Goatley, K, Fortmann, NE en Buckley, CA (1988) Upgrading of municipal anaerobic digesters and activated sludge processes through the use of cross-flow microfiltration. Paper presented at the CSIR/WISA/WRC/DWA Symposium on Sludge Handling, Pretoria. November.

Blackbeard, JR, Gabb, DMD, Ekama, GA en Marais, G v R (1988) Identification of filamentous organisms in nutrient removal activated sludge plants in South Africa. *Water SA* **14** (1) 29-34.

Bloom, B, Bourne, DE, Sayed, AR en Klopper, JML (1988) Morbidity patterns from general practice in Cape Town. A pilot study. *S. Afr. Med. J.* **73** 166-168.

Botha, JF en Verwey, JP (1988) Cross-borehole packer tests as an aid in modelling ground-water recharge. *Proc. VIIth International Conference on Computational Methods in Water Resources*, Springer-Verlag, New York.

Bourne, DE en Bourne, LT (1988) Liquid consumption patterns in greater Cape Town. Paper presented at the 14th Biennial Conference of the International Association for Water Pollution Research and Control in Brighton, UK. July.

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