REPORT

of the

COMMISSION OF ENQUIRY

into

WATER MATTERS

Published by Authority

REPUBLIC OF SOUTH AFRICA

R.P. 34/1970

FINDINGS

I. The Water Resources of the Republic—Available Supplies and Estimated Future Usage

(1) *The available supplies*

South Africa lies in the drought belt of the globe—consequently it is a dry country. The west is drier than the east and the lower the rainfall the more unreliable it is. Although over the geological ages there have been great changes, the climate of historical times, that is for as long as reliable data have existed, has in general remained much the same. The question therefore is not how the drought problem can be solved but rather how we can make best use of the various water resources at our disposal.

The average annual runoff from the Republic (i.e. the average annual quantity of water that reaches our rivers) is put at 52 × 10⁹ M³ (20 million morgen feet) per annum, or 143 200 × 10³ m³d. (31 500 m.g.d. million gallons per day). Because of unavoidable losses by spillage and evaporation from storage, and the fact that not all runoff can be diverted for use before reaching the sea, it has been accepted that only 40% of the runoff, or an average of 57 280 × 10³ m³d. (12,600 m.g.d.), can be regarded as the assured proportion that can be made available for use through the provision of storage. In this estimate the position with regard to our neighbour states has been taken into account.

Several measures can be applied, however, to enhance appreciably the assured yield of our storage works. Moreover, by application of the results of further investigations, it may be possible to regulate a somewhat greater proportion of the runoff by means of storage. Indeed, it should be possible to push up the utilisable surface waters of the Republic to about 50% of the mean annual runoff, i.e. to 26 × 10⁹ m³ (10 million morgen feet) per annum, or 71 370 × 10³ m³d. (15,700 m.g.d.).

To arrive at the total usable natural water resources of the Republic, the potential groundwater yield must be added. Unfortunately, however, it is not possible at this juncture to make reliable estimates of the safe yield of our groundwater resources. It is reasonably certain, however, that present consumption could be doubled if sufficient were known about the occurrences and replenishment of groundwater. For the sake of conservatism the Commission has taken into account only the current estimated total abstraction of about 3 090 × 10³ m³d. (680 m.g.d.) from our groundwater resources.

It may be accepted with a measure of confidence that, given thorough investigation, research and planning together with the necessary financial means, about 27·4 × 10⁹ m³ (10·5 million morgen feet) per annum, or 75 010 × 10³ m³d. (16,500 m.g.d.), can be made available from natural water resources.

(2) *Present and expected future consumption*

The future consumption of water will be influenced by increasing population, rising standards of living, and growing demands for irrigation water and by industrialisation and urbanisation of the South African economy.

Rates of increase in consumption for irrigation and stockwatering have been fairly constant since the year 1910. By 1965 consumption for these purposes had reached an average of 20 985 × 10³ m³d. (4,616 m.g.d.), or 83·5% of the total water consumption throughout the country. Expectations are that by the close of the century, with current methods of utilisation, the total for irrigation will have become about 34 780 × 10³ m³d. (7,650 m.g.d.), of which roughly 32 280 × 10³ m³d. (7,100 m.g.d.) will have to be provided from permanently developed surface water resources.

Till recently water resources in the Republic have been developed and used chiefly for agricultural purposes. South Africa's economic development, however, is conforming closely to the standard international pattern—a pattern in which, during the process of economic growth, contributions to the gross national product by the primary sectors, agriculture and mining, show a relative decline with rising *per capita* incomes while those of industry reflect a proportionately steep rise. This evolution will be accompanied by increasing urbanisation and rapidly rising water consumption for urban and industrial purposes.

In contrast with the use for irrigation, the increase in the use of water for urban and industrial purposes has not occurred at a constant annual rate. At 3·4% per annum up to the year 1933 the increase was comparatively slow, but onwards to 1965 it accelerated to about 7%. If this growth rate is maintained, the water demand for urban and industrial use will reach about 45 460 × 10³ m³d. (10,000 m.g.d.) by the end of the century. If the proportion abstracted from groundwater is maintained at the present 10%, 40 900 × 10³ m³d. (9,000 m.g.d.) will have to be derived from permanent surface sources by the close of the century.

The adopted rate of increase in water demand for urban and industrial purposes is indeed very high. It has been projected linearly on a semi-log plot and represents a 7% per annual increase rate over the years 1940-2000. However, since there seem to be just as many factors tending to increase the water demand as there are working in the opposite direction, the Commission feels the foregoing figures should be adopted for planning purposes. Galloping water demands constitute just one of those unavoidably explosive results of incorporating a compound growth rate into an economy. For purposes of medium-term planning, actual consumption trends must be continuously reexamined to ensure that adequate water supplies for urban and industrial use are, as far as possible, provided five years in advance. Similar studies are needed also to ensure that long-term projections conform to actual growth rates. If estimated increases in demand materialise, total water needs will rise to 80 240 × 10³ m³d. (17,650 m.g.d.) by the turn of the century.

(3) *Preserving a balance between supply and demand*

Seeing that assured yields in the Republic are estimated at only 60 460 × 10³ m³d. (13,300 m.g.d.), with a potential maximum of only 75 010 × 10³ m³d. (16,500 m.g.d.), the rapidly rising demands, if they materialise, will exceed maximum estimated yields even before the close of the century. If account is taken also of the facts that the available water resources are very unevenly spread geographically, that three-fourths of the runoff is derived from only one-third of the land area and that our most important metropolitan regions do not happen to be located on major rivers, it becomes evident that urgent regional problems may crop up long before the close of the century.

Solutions to the problem may be sought along three main paths. First, we must strive for improved methods of development and utilisation of our natural water sources. Secondly, we must raise the efficiency of current use of developed supplies; the most obvious methods lie in the re-use of effluents and improved efficiency in the use of water for irrigation. Finally, we must seek ways of creating new sources of water; probably the desalination of sea water would make the biggest contribution. If the efficiency of water use for irrigation could be improved to the extent that the same crop yield per morgen was maintained with a 25% reduction in water application and if municipal effluents could be re-used in two cycles, the total demand from natural sources at the end of the century will be only $52\,300 \times 10^3$ m^{3}d. (11,500 m.g.d.) as against $80\,240 \times 10^3$ m^{3}d. (17,650 m.g.d.) without the improved utilisation techniques. Solutions along these lines are analysed in Part II of the report. If these savings materialise there will still be a surplus available in the year 2000. However, the task will make very substantial demands on our human and material resources.

(4) *Food production and the use of water*

In regard to most of the important agricultural and horticultural products the Republic is self-sufficient. There is every reason to believe that normal technological advances in farming, supported by research and extension services provided by state and private enterprise, will suffice to maintain at least the present degree of self-sufficiency till the end of the century without the need of any additional dryland or irrigation land for raising more of these products. In respect of a few products, such as wheat (and also rice, of which little is produced at present) it will evidently be necessary to continue to rely to some extent on importation. If State research and extension services were to lay greater emphasis on these products, however, it is possible that even in these products a greater measure of self-sufficiency could be achieved than at present. This applies particularly to wheat. On the other hand, it seems fairly certain that importation will in general be more advantageous than attempts to raise local productivity if this entails opening up new irrigation land. In regard to strategic considerations it must be recognised that emergency situations affect not only importation sources but also export channels. In such events, land normally utilised for export production would become available to overcome shortages in specific products.

In respect of some animal products used for human consumption, the Commission finds that production indeed lags behind demand and that there is therefore to a fluctuating degree dependence on imports. The outlook is moreover that dependence on imports will persist beyond the close of the century unless successful steps can be taken to improve productivity in cattle farming. In South Africa, productivity in ranching has lagged behind that in agriculture and horticulture and so there is reason to presume the potential exists for appreciable improvement, among both White and Bantu farmers, in the local production of foods of animal origin. The State's agricultural research and extension services should therefore give particular attention to this aspect. By contrast, irrigation at present plays a relatively minor role in meat production and whether it will contribute economically in future depends, among other things, on future trends in the relative prices of beef and agricultural products and in the people's meat consumption habits. Moreover, in view of the fact that South Africa's import sources, especially of meat, seem to be reasonably assured, the costs of the additional irrigation facilities that would be needed for meeting local shortages of these products must be carefully weighed against the alternative of relying on importation. For dairy products, especially butter, it should be possible in emergency to find substitutes without undue local disruption.

On the basis of experiences of the past and foreseeable developments of the future, the Commission finds it unlikely that either export markets or internal processing industries for agricultural products will in general offer sufficient growth potential to warrant according high priority to expansion of land areas under irrigation. Exceptions to this generalisation are to be found, however, in such products as deciduous fruits, citrus, leaf tobacco, sugar and wine. These products, most of which can be raised under supplementary irrigation and therefore with relatively modest applications of water, contribute substantially to the gross national product and to the country's export trade.

The Commission's general finding is thus that there is no urgent need to accord high priority to the provision of additional irrigation facilities for the benefit of agriculture. On the contrary, the emphasis in agricultural production policy should be placed on more efficient use of existing production facilities and this includes existing irrigation lands. The measures needed to achieve this, such as continued research and extension of facilities, as a rule cost far less than the alternative, viz. the provision of additional irrigation land. To take care of possible emergencies, it might be desirable, if this has not already been done, to draw up emergency plans for the switching of land (both dryland and irrigation land) from raising produce of which the country has a surplus to raising produce that is normally imported.

This finding should not of course be construed as meaning that, except for the products mentioned, strictly no new irrigation projects should be tackled to the benefit of agriculture. It is meant merely to emphasise the principle that justification for such projects should, in each specific case, be based on careful socio-economic analysis, the weighing of costs and benefits against those associated with alternative allocation of funds and of the water that would be demanded.

(5) *Available water supplies and the future needs of the most important urban and industrial areas*

Industrial activities and population are highly concentrated in specific areas of the Republic, so much so that in 1960 the four most important metropolitan regions produced no less than 80% of the country's manufactured articles and provided work opportunities for 78·5% of the industrial labour force.

Of particular importance is the Southern Transvaal industrial complex, which is responsible for 45% of the country's industrial production. This region is dependent for its water mainly on the Vaal. The assured yield of the present Vaal Dam is $2\,823 \times 10^3$ md. (621 m.g.d.). By means of schemes already planned, for the bringing of water from other catchments, for the provision of additional storage facilities within the Vaal basin and for the application of sound management practices, the assured yield can be pushed up to 11 820 × 10^3 m³d. (2,600 m.g.d.). With two-cycle re-use of 50% of the water drawn from the system, it is estimated that the total demand in the catchment may well rise as high as 9 550 × 10^3 m³d. (2,100 m.g.d.) by the close of the century. There will thus in fact be a slight margin for future development. Although it may turn out to be lower than indicated, predicted usage for planning purposes can be established only through careful study of consumption trends. Neither demand nor supply can, however, be regarded as fixed quantities but rather as quantities that can be influenced by price and administrative policies. If there is a reasonable decentralisation of economic activity and the appropriation of adequate funds, sufficient water can without doubt be made available to meet the ever-growing needs of our largest metropolitan complex.

The Western Cape embraces a second important node of economic activity. Its water demand is expected to increase from the 1965 level of 245 × 10^3 m³d. (54 m.g.d. to 1 246 × 10^3 m³d. (274 m.g.d.) by the year 2000. If all available supplies are exploited and reasonable re-use of sewage effluents is introduced, sufficient water can be made available for the foreseeable future. Thereafter, the desalination of sea water will provide for future needs.

A third important industrial region is the Durban-Pietermaritzburg complex, which is expected to grow rapidly. It is estimated that water usage will rise from the present 455 × 10^3 m³d. (100 m.g.d.) to about 1 800 × 10^3 m³d. (400 m.g.d.) by the close of the century. When the catchments presently being tapped have reached full development and water has been brought in from the Umkomaas, there will be sufficient water, with efficient re-use, to meet requirements till the beginning of next century and thereafter sources such as the Umzimkulu and Lower Tugela can be exploited. In regard to water the future of this region is therefore assured.

Port Elizabeth-Uitenhage is the fourth important metropolitan zone. Water demands have risen sharply during the post-war years and expectations are that usage will increase from the present 90 × 10^3 m³d. (20 m.g.d. to about 730 × 10^3 m³d. (160 m.g.d.) by the end of the century. The area is assured of sufficient water for the foreseeable future and, being near the coast, can always fall back on the desalination of sea water.

Bloemfontein can draw adequate water for its future requirements from the Caledon River.

To meet its rapidly increasing demands, the Witbank-Middelburg area can obtain water from the Olifants in quantities sufficient only till about 1980. Thereafter, additional supplies will have to be derived from the Steelpoort or elsewhere.

Fortunately, the largest of the Bantu homelands are situated on the eastern escarpment, which is blessed with the country's richest water resources; water supplies for the homelands and decentralised border industries will therefore offer little difficulty. From the water supply point of view, the Tzaneen-Phalaborwa, Tugela basin, Richard's Bay-Empangeni, and East London-King William's Town regions are all extremely well suited to large-scale decentralisation.

The centres immediately to the north of the Southern Transvaal complex, such as Rosslyn, Brits and Rustenburg, will have to remain partly dependent on the Vaal. Temba can be supplied from the Pienaars River and the Pietersburg-Potgietersrust region will eventually have to draw water from the Olifants.

II. Measures to Maintain the Balance Between Supply and Demand—Efficient Management and Control of the Country's Water Resources.

(6) *Introduction*

As explained in chapter 1, unless the essential steps are taken to plan the exploitation and augmentation of our water resources, to conserve and re-use our available supplies, and to manage and control our resources in the most efficient manner, serious shortages will be suffered somewhere before the close of the century. Following on from Part I, Part II sets out the measures that must be adopted to maintain a continuous balance between the available supplies and sharply rising demands.

(7) *Efficient storage of water*

Attempts to raise the net assured yields of our storage works may be approached from three angles: first, the possibility of rendering a greater percentage of river flow available for use by means of suitable storage; secondly, the efficient management of available supplies and, finally, the elimination of unbeneficial water works.

Belonging to the first group are attempts to raise the yields by planned siting of dams. A purposeful programme should be launched for the investigation of all possible sites where dams can be built in order that it may be possible to determine with confidence the maximum utilisation of the runoff of our rivers. In the selection of dam sites, special attention should be given to the reduction of evaporation losses.

The second group embraces the application of advanced control systems for the management of dams to ensure improved yields. In managing a multi-purpose scheme that has to meet competing needs within a region, the aim must be the optimum yield and utilisation of the available water supplies.

To the final group belong attempts to limit the numerous small farm dams that merely lead to unnecessary evaporation losses; construction of these should be permitted only where the advantages fully compensate for the concomitant evaporation losses and runoff reduction.

The implication is that in principle there should be some control over all dam-building to ensure that in future storage of water will be beneficial to the country as a whole. Such control must, of course, be exercised in such a way that it will not be a hindrance to sound, desirable agricultural development.

(8) *Reduction of evaporation losses*

Although the percentage diminishes from west to east and varies considerably from place to place, on the average about 27% of the water that our existing dams can deliver is lost by evaporation. Reduction of this loss will raise the assured yield of our storage dams. Methods that have already enjoyed attention include the application of protective layers to water surfaces, the construction of larger and deeper reservoirs, the siting of dams in regions of low net evaporation, and the storage of water underground. As evaporation loss is much greater from full than from part-full reservoirs, it follows that losses will be lessened by operating reservoirs according to the variable draft procedure. The application of correct management procedures, especially where there are multiple dams in a single basin or in separate interlinked catchments where evaporation loss rates differ, can help considerably to keep losses as low as possible.

(9) *Underground storage of water and augmentation of our water resources from groundwater sources*

Where aquifers are located deep enough to avoid losses through evapotranspiration and if leakage can be eliminated, underground storage will permit us to exploit more of our available water. Unfortunately it is not yet possible to assess quantitatively the potential contribution of our groundwater resources. It has been proved, however, that there is no question of a progressive country-wide drop in groundwater levels and gradual exhaustion of groundwater resources. It has been found that, although over-pumping is going on in a number of areas with the resultant steady depletion of stored groundwater, the underground resources of the country as a whole are not being fully exploited. It is essential that those areas where groundwater sources are being or are clearly about to be overtaxed be identified as quickly as possible and declared subterranean water control areas. Further development in such regions must then either be frozen or allowed only under permits embodying strict conditions.

Over the major part of the Republic natural replenishment of groundwater takes place every year. In some parts, especially those with dense vegetation and summer rainfall, recharge occurs irregularly but areas that enjoy no replenishment are very limited. The drying up of numerous boreholes annually is largely ascribable to the extremely limited storage capacities of the sources and to the fact that boreholes are injudiciously distributed, with the result that as a rule the sources are only partially exploited. On the other hand, there are areas where the groundwater reservoirs are comparatively large and where total abstractions should definitely be restricted to the average annual recharge. Safe yields of such groundwater sources can, however, be increased by artificial recharge. Judicious development of groundwater sources can be achieved only on the basis of comprehensive surveys and yield determinations. Our knowledge of the groundwater resources of the Republic is unfortunately limited. Only a few groundwater compartments have been fully surveyed and the available information is thus quite inadequate for any long-term resource planning.

(10) *The state of preservation of catchments*

There is a close relationship between soil conservation and the harvesting of water from catchment areas but the interplay is highly complex. Soil conservation is promoted by dense vegetation, which inhibits soil erosion, delays storm runoff and encourages infiltration. Nevertheless, vegetation needs water to sustain itself. Because of interception and transpiration, particularly by dense evergreen forests or plantations and by hydrophytic plants in vleis, the total water yield and low flows during the long dry seasons are diminished. Much more runoff occurs from a bare soil surface but, because of reduced infiltration, flood peaks are raised and percolation, which feeds the rivers during dry seasons, is decreased and the runoff is consequently less sustained. Increased soil erosion from bare surfaces also greatly aggravates the silting of storage works.

The ideal from the point of view of water yield thus lies between the two extremes of the complete preservation of the soil and the total exposure of the soil to erosion. Optimum treatment for each region must be decided according to local circumstances and the nature of the vegetation. Plants that thrive during the rainy season and are dormant during the dry season will have a less detrimental effect on the low flow yield. To derive maximum advantage from the available water and associated soil it is important to create a cover of useful and beneficial vegetation.

As a result of increasing water consumption, evidently in the main owing to the intensification of agriculture, some regions have, according to gaugings over the past twenty years, experienced marked reductions in runoff per unit of catchment rainfall. Large reductions, however, are confined exclusively to two-thirds of the country's area, which yields a mere 15% of the runoff, and therefore do not as yet constitute a threat to the water resources of the land as a whole. The phenomenon is nevertheless posing serious regional problems for riparian owners along the lower reaches of rivers in the arid parts of the country. In some of the mountain catchments of the Eastern Transvaal, large-scale afforestation especially of former grass-covered mountain slopes on which the vegetation used to be dormant for part of the year, has established a dense evergreen vegetal cover and reductions in runoff by as much as 30% appear to have taken place. It is important that more quantitative information be gathered on the influence of afforestation on runoff so that it may be established with certainty to what extent and in which regions the consumption of water by plantations can be regarded as a beneficial use of water from the point of view of the overall economy.

The state of catchment conservation has an important bearing on the sediment loads in the rivers. Where rainfall is comparatively high and vegetal cover satisfactory, sediment loads are usually low. Tendencies to soil erosion, with consequent increases in sediment content of river flow, however, are in some areas aggravated by the nature of the geology.

Measurements of sediment loads in our rivers reveal that there are wide variations in the average percentage of material in suspension from river to river. As a volumetric percentage, mean silt movement seems to be 0·53% of runoff, implying a total annual average sediment load of $276\,700 \times 10^3\ m^3$ (106,000 mg.ft.).

The deposition of sediments and manner of distribution of the silt in reservoir basins greatly affect the useful life of storage, the acquisition of land for storage basins, and the costs of measures to prevent silting.

Apart from the great expense associated with the raising of a dam to retrieve lost storage volume, in the long run the major disadvantage of silting is that deeper parts of the basin fill up the most quickly with silt. The result is that with each raising of the wall, for a given storage capacity, there is an increase in the water surface area exposed to evaporation. This means that evaporation losses increase and, with continued raising, become so large that eventually the basin is no longer of value as a storage unit. It is thus very important that silting be combated as energetically as possible to ensure that our available water can be effectively stored for use.

There can be no doubt that the best protection against the silting of storage works is to be accomplished by arresting at source the sediments that reach our rivers. Correct land management is thus of cardinal importance in the combating of siltation.

Regarding the state of conservation of catchments, it must unfortunately be confirmed that, in spite of encouraging progress with soil conservation in limited parts of the country, the condition of many of the important mountain catchments as well as of the lower-lying parts of our drainage regions is still highly unsatisfactory.

According to the report on "Conservation of mountain catchments", which appeared in 1960, 14% of the catchments were then in good condition, 76·5% average, and 9·5% poor.

Subsequent observations in 90 of these areas reveal that conditions in 16·6% of them have improved, 43·3% have remained much the same and 40·1% have deteriorated still further. The state of conservation in many of the lower-lying parts of our drainage regions also leaves much to be desired. In fact, there is scarcely a single part of the country where soil and vegetation have not to greater or lesser extent been damaged.

The most important reasons for deterioration in the state of conservation in many catchment and drainage areas are to be found in the primitive and inefficient farming practices still being applied in large areas of the country and the continued injudicious burning of mountain slopes, especially when accompanied by mismanagement and misuse. This unsatisfactory state of affairs must be ascribed partly to the ignorance of the inhabitants, partly to tradition, especially among the Bantu, partly to lack of interest, and partly to the proliferation of sub-economic farming units.

On the question of burning in mountain catchments, the Commission's opinion is that in the arid mountain catchments and mountain kloofs the advantages are not outweighed by the disadvantages, but that a judicious rotational burning system in the higher rainfall parts—excluding mountain kloofs—may well be justified.

Clearly, as there is a general conflict between the interests of individual landowners and the broad national interest, the Commission is of the opinion that the protection of all important catchments is a matter for which the State must, in large measure, accept responsibility. It is in fact essential that the measures undertaken by official bodies to check soil erosion and to effect stability in the potential water yields of our catchments be accelerated. In this connection watercourses deserve special attention.

(11) *Hydrological planning of catchment development*

From the foregoing review of the various aspects of soil and water conservation it seems that the two concepts are not always synonymous. The best management of a catchment must in fact be a compromise whereby as little as possible of the water that is not being beneficially utilised should be held back, consistent of course with avoiding soil erosion. To obviate a clash, it is important that the work on erosion control be co-ordinated with that on water conservation.

In Chapter 6 it was proved that shortages before the close of the century in any of the most important agricultural products in South Africa were highly unlikely and therefore there seems no reason why any region suitable for afforestation should be reserved for agricultural purposes or why afforestation should be restricted so that the water resources may be reserved for future irrigation purposes. Normal fluctuations of economic factors may in due course provide a decisive answer to this but, in any event, the matter can always be reviewed as and when plantations now established reach maturity and are clear-felled.

Where expansion of afforestation is endangering established irrigation or other water utilisation developments, however, restrictions should be imposed. Full consideration should in any event be given to the economic benefits of afforestation, the probable costs of storage schemes to overcome water shortages and the economic justification for expanded development.

A policy which has been applicable since 1934, namely that of State acquisition by negotiation or expropriation of mountain catchments deemed vital for water conservation, should be retained, but steps should be taken to accelerate the process so that the most important mountain catchments can become State property within a reasonable time.

In the transition period while mountain catchments are being purchased by the State, as many of these areas as possible should be declared catchment control areas in terms of the Water Act of 1956, and should be managed with a view to protecting the water sources.

To avoid clashes of interests that arise among various consumers as the result of rising demands for water it is desirable that the manner and purpose of water utilisation within each catchment be timeously determined and that planning and subsequent action accord with such determinations.

The Minister of Water Affairs could with advantage invoke his powers under the Water Act to insist that, where afforestation schemes have been or are about to be established in catchment control areas, such schemes be managed in accordance with conservation directives laid down by him for each specific afforestation project. It is considered particularly desirable that the Departments of Agricultural Technical Services, Agricultural Economics and Markets, Water Affairs and Forestry should make joint recommendations for these directives.

Often referred to as "sponges" and presumed to detain stormwater during the rainy season and slowly release it during low flow periods, some vleis frequently turn out in fact to be mere consumers of water; yields would in most instances be increased if they were to be drained and such vlei vegetation as has no value replaced by useful crops. On the other hand, many vleis do indeed provide good grazing. Drainage of vleis is of course permissible only if executed in such a way as not to lead to soil erosion. The whole subject demands careful investigation.

(12) *Control of flooding*

Although the problem has never as yet assumed major dimensions in South Africa, appreciable damage is from time to time wrought by floods.

Control of flooding is of importance in protecting and augmenting our water resources from two particular points of view. On the one hand, appreciable additional quantities of water can be retained in storage through improved flood control and be made available over an extended period; by regulating storage on a variable draft basis beneficial use can be made of the water while, on the other hand, silting of storage can be delayed.

Application of sound hydrologic and hydraulic principles and promotion of soil conservation measures can contribute to the solution of flood problems. Steps should also be taken to control development within the flood plains so as to obviate the damage suffered during inundations.

(13) *Desalination*

Desalination of sea water to augment fresh water supplies to development nodes along the south and west coasts of the Republic will become indispensable within the next two to three decades if urban and industrial development is to continue. Current research assessments of the economics of desalination hold out promising prospects for production of fresh water from sea water for urban and industrial purposes. Where economic circumstances are favourable, sea water desalination combined with power generation is being put into practice in several overseas undertakings, all of which at present use fossil fuels. It follows that the discovery of oil and combustible natural gas at the coast, as also the development of nuclear energy on an economic basis, would considerably aid the large-scale desalination of sea water.

Although on economic grounds the use of desalinated sea water solely for irrigation purposes holds little or no promise, the benefit-cost structure of a combined power generation and desalination unit of the order of 227×10^3 m^3 d. (50 m.g.d.) capacity might well, under favourable circumstances, become attractive for indirectly assisting irrigation. In the western Cape, for instance, desalinated sea water could largely relieve the urban and industrial areas of their dependence upon the rivers and river catchments and consequently promote the profitable irrigation farming of the region.

The development of economic desalination processes would make possible the following—

(i) the unrestricted re-use of purified industrial sewage effluents in a closed water system. In an urban water economy, cumulative utilisation will lie between 1·4 and 1·8 m^3 (300 and 400 gallons) for every 0·5 m^3 (100 gallons) of fresh water introduced into the system depending on losses in the water reticulation-sewage cycle; and

(ii) the reduction of mineral pollution of fresh water sources and consequent increase in the usage value of mineralised effluents.

Research currently being undertaken by the Council for Scientific and Industrial Research into the desalination of sea water should, in the opinion of the Commission, be intensified in collaboration with other interested organisations and placed on a feasibility basis.

(14) *Re-use of water*

By practising multiple internal recirculation of water and effluents in factory processes, the fresh water intake can be reduced by between 50% and 90%. Furthermore, research work carried out in practical situations has proved that factory production can be pushed up by 50% to 100% without raising the fresh water demand.

Between 60% and 100% of the fresh water intake to factories and residential areas reaches the sewage treatment works, and in a rather limited number of cases purified effluents are re-used for a variety of purposes. On the Witwatersrand, for instance, only 20% is re-used by industries and power stations.

As a result of the development by the C.S.I.R. of advanced techniques for the conversion of purified sewage to class A water, and the successful transfusion into the water mains at Windhoek, it is economic and practicable to establish the reclamation of sewage effluents as an integral part of the water economy within the urban and industrial areas and in major towns. It is feasible to meet 50% of the water demand from reclaimed water; two-cycle re-use is equivalent to making available an additional 75% of the original fresh water intake. It is therefore imperative that the research work of the C.S.I.R. in this field be placed on a feasibility basis in collaboration with other interested organisations.

(15) *Further savings in urban water use*

The domestic use of water can be reduced in many ways without lowering living or health standards or unnecessarily burdening consumers. It must be brought home to them that even though squandered water can be reclaimed, this requires additional capital outlay and running costs. Substantial savings can be effected by modifications in the type and size of toilet facilities, improved water use methods, elimination of leakage, and pressure regulation at distribution points.

Experience has also proved that water consumption invariably declines when individual metering is introduced and each family pays according to quantity used. An appreciable reduction in water use can be effected by installing individual water meters for all industrial and domestic consumers, including individual flats and non-White dwellings.

Large erven and gardens, which have in the past been traditional in South Africa, also promote the excessive use of water. In areas where inordinately large quantities of water are needed to maintain gardens, plots will in future have to be restricted to reasonable size.

(16) *Prevention of pollution*

Pollution of the Republic's rivers, through the discharging of industrial and domestic sewage effluents and the shedding of stormwater from urban, industrial and mining areas and from cultivated, irrigated and over-grazed lands and through seepage from irrigation areas, has already, to a greater or lesser degree, detrimentally affected fresh water sources. Pollution by mineral salts, particularly those derived from irrigation seepages, industrial and mining effluents, and storm runoff from mining areas, has already created serious problems.

In some of the Republic's urban and industrial areas —for instance, the Witwatersrand region—the capacity of rivers to limit the deleterious effects of mineral pollution by dilution has reached breaking point. It has accordingly become essential to protect the Republic's fresh water sources in regions where mineral pollution has assumed serious proportions. This can perhaps best be accomplished by creating closed saline water control systems, planned in such a way that the waters are used for recreational, industrial and other purposes that do not demand mineral-free water. Moreover, these bodies of water can be planned as sources for mass-production demineralisation plants.

The most effective means of controlling pollution by industrial and domestic sewage effluents lies in the re-use of water and the reclamation of effluents. The organic pollution load in industrial effluents can be efficiently removed if mixed with domestic sewage and the two types of waste purified in conventional sewage treatment works. In this way the reclamation of purified effluents for re-use would be promoted. It stands to reason that industrial effluents should be discharged into municipal sewers the better to control pollution and promote re-use. On the other hand, it is essential that local authorities institute strict control measures because effluents from some industries contain chemicals that detrimentally affect the re-use value of the treated effluent.

(17) *Water savings in power generation*

The quantity of water consumed per unit sent out varies from 0·006 m^3 (1·3 gallons) per kWh in the old stations to 0·004 m^3 (0·9 gallon) per kWh in the modern stations.

Tests currently being undertaken by ESCOM hold out prospects of reducing the water consumption in "wet" cooling systems to about 0·003 m^3 (0·6 gallon) per unit sent out.

If the use of "dry" cooling systems, with which ESCOM has already made a start, proves technically and economically acceptable, water consumption may drop to 0·00068 m^3 (0·15 gallon) per unit sent out.

It is predicted that the installed capacity of power stations in the Republic at the close of the century will be 68,000 MW. If it be accepted that half the energy demand at that time will be met by nuclear power stations located at the coast and the remainder from coal-fired stations in the interior, the capacity of inland stations, allowing appropriate load factors, will be 45,000 MW. If "wet" cooling is then still in use, the water consumption for power generation will be $1\,227 \times 10^3$ m^3d. (270 m.g.d.), of which an appreciable proportion will be derived from the Usutu complex. On the other hand, if all new coal-fired stations beyond the first 10,000 MW are equipped with dry cooling systems, the water consumption for power generation at the end of the century will be only $511{\cdot}4 \times 10^3$ m^3 d. (112·5 m.g.d.). The possibility of bringing about savings of such magnitude clearly calls for efforts in this direction to be pursued with energy and perseverance.

By making full use of the Republic's small but valuable hydro power potential, by importing power from contiguous regions, by establishing nuclear stations at the coast, and by adopting water-saving measures at coal-fired power stations, much can be done to reduce water consumption. It is nevertheless evident that appreciable quantities of water will have to be reserved for power generation purposes.

(18) *Improvement of irrigation techniques*

Agriculture is by far the major consumer of water. Efficient control and utilisation of water by this sector is therefore of utmost importance in the drawing up of a national water plan for the future.

There seems little doubt that the irrigation techniques currently employed and the irrigation scheme layouts adopted often lead to waste of water. Leaky dams and furrows and faulty physical planning are also frequently responsible for wastage of water. Resultant waterlogging and brack are aggravated by the fact that in the planning and layout of irrigation schemes adequate provision has not always been made for effective drainage systems.

Among many irrigation farmers, knowledge of the basic requirements of efficient irrigation and water utilisation is lacking.

Enlightenment of farmers in the agricultural and engineering aspects of irrigation practice must enjoy high priority otherwise efficient use of irrigation water will not be achieved. Such enlightenment should be closely linked with the provision of water by the Department of Water Affairs and, consistent with good farming practices, emphasis should be laid on economic aspects in order to achieve the maximum yield per unit of water. To promote enlightenment in basic knowledge it is regarded as essential that an irrigation research institute be established where the relevant departments and other organisations can co-operate in this sphere.

The planning and development of irrigation schemes should not be over-hasty and must not precede the acquisition of essential information, such as the results of soil surveys. For rational planning it is necessary that a master plan be compiled by all interested organisations, in which all facets are gathered together to form a unit and are evolved according to plan. Success demands the closest co-operation and co-ordination among the various departments and other interested organisations. In the past this essential requirement has very seldom been met.

Thorough knowledge and evaluation of the soil forms the basis of efficient planning of an irrigation project and this can be gained only if effective soil surveys precede the planning. Because of inadequate staff, however, it has seldom been possible to complete the necessary soil surveys.

The Commission is of the opinion that, if the shortcomings referred to can be overcome, the struggle towards a 25% saving of irrigation water per unit of production can succeed.

(19) *Forecasting of climatological conditions*

Very great advantages in the management and practical utilisation of our water resources would follow if a measure of reliability could be achieved in the long-term forecasting of climatological conditions. If rainfall for a year ahead could be predicted with some certainty, advance decisions could be taken, with the result that the available water resources could be more efficiently utilised.

For some time past, attempts have been made to establish a correlation between rainfall and sunspot cycles, but in South Africa there seems to be little connection between sunspot activity, or changes in the intensity of sunspot activity, and rainfall.

Bearing in mind the enormous capacity for heat storage in the oceans compared with that of the atmosphere, there can be no doubt that long-term insolation changes are reflected in the sea and thus affect atmospheric turbulence. Consequently it is possible that major long-cycle fluctuations in the weather are brought about by measurable changes in the oceans. Attempts are currently being made on an international scale to acquire the necessary oceanographic data with the aid of sophisticated electronic devices.

The Commission regards it essential that research and attempts to acquire the necessary data to make long-term weather forecasting possible be actively supported.

(20) *Extraction of water from atmospheric moisture*

It is estimated that only about 5% to 10% of the moisture content of the air mass moving over a country reaches the ground surface in the form of rain or snow. Methods of extracting and using more of the remaining moisture have already enjoyed much attention but considerable research is still needed. According to tests carried out elsewhere, condensation of moisture droplets in a cloud can be triggered by the artificial introduction of suitable nuclei such as silver iodide and indications are that in favourable circumstances rainfall can be increased by as much as 20%. Another possibility is the extraction of moisture from the atmosphere by means of condensation screens. At this juncture it is not possible to say with certainty to what extent our water resources can be augmented through activities of this type. It is considered essential, however, that research in these spheres be promoted by the Department of Water Affairs in collaboration with the Weather Bureau and other suitable bodies, such as the C.S.I.R.

Analyses of the characteristics of South Africa's climate, and the circumstances associated with the occurrence of deserts alongside oceans, inland seas and lakes, indicate that the building of dams or the creation of lakes, as envisaged by the so-called Schwarz Scheme, would have practically no influence on rainfall in South Africa.

(21) *Variable draft*

Our water resources, whether underground or surface, have their origin in the rainfall. Rainfall and runoff, however, fluctuate from season to season and from year to year, and losses are suffered through evaporation. The larger the capacity of storage dams, and the lower the rate of evaporation, the greater the degree of control we can exercise over our water resources. If storage provision were to be infinite and evaporation nil, river flow could be regulated to a constant value equivalent to the long-term mean annual runoff.

The difficulty in the Republic, however, is that runoff is extremely erratic and that evaporation rates are inordinately high. If utilisation is restricted merely to the assured yield, which is fixed by the most severe drought to be expected, large quantities of water would during normal and wet years be lost by evaporation or would escape over the spillways of dams. It would be far better to use surplus waters for purposes that do not demand a very high guarantee than to allow large quantities of water to escape from storages that are held as full as possible to guarantee yield during the most severe drought. If we can categorise demands according to priority, and therefore according to the degree of assurance with which the demands must be met, storages could be so regulated as to satisfy requirements in optimal manner.

A variable draft policy is especially applicable to the management of a multi-purpose scheme or one comprising linked catchments having different evaporation rates and meeting various kinds of demands. By employing sophisticated modern techniques it is possible to predict, six months in advance, the storage reserves needed to satisfy the various uses according to the required degree of assurance. In years of normal or better than normal runoff appreciable quantities of water that otherwise would be lost can be beneficially used for irrigation, for which a high degree of assurance is not imperative. During a year of poor runoff the supply would have to be appropriately curtailed.

Farmers can be informed prior to planting time as to the available water supply. By these means water utilisation efficiency in a multi-purpose scheme can be increased by between 10 and 20%. It must be recognised, however, that major fluctuations in the water supply to irrigation schemes may have undesirable agricultural and economic repercussions. The degree to which the variable draft policy can be employed must therefore be thoroughly investigated under guidance of the proposed Water Affairs Committee.

(22) *Systems analyses*

As the various centres to be supplied increase in number and become more diversified and as the water sources to be exploited multiply, so decisions as to the best sequence of development of the various resources and operational procedures to be adopted become more complex. Advanced techniques based on systems analyses have been designed to ensure the optimal management of multi-purpose multi-unit schemes. Application of systems engineering methods by experts in this field can lead to appreciable increases in the assured usable yield. The Commission considers that these methods of planning and managing our water resource developments should be adopted and that suitable personnel be recruited and trained in the techniques.

(23) *Adoption of a suitable price policy*

The application of a realistic price policy that reflects underlying scarcities is one of the most efficient ways of ensuring the effective exploitation of a country's resources. In a free economy it is moreover the best way of effecting a balance between supply and demand and preventing waste of a scarce commodity. It is therefore undesirable that the price of water, either to the urban or to the agricultural sector, be kept artificially depressed through administrative decisions.

In the past, water has largely been regarded as an asset provided free by nature, and the unrealistically low prices paid by farmers on Government irrigation schemes do not even cover the operation and maintenance costs. Such a policy has had the deleterious effect of encouraging the wasteful use of water. Farm budgeting data reveal that in the Republic water rates constitute a lower percentage of production costs than in other countries and that water costs represent a negligible proportion of the gross costs of crop production under irrigation. Moreover, it is clear that the production costs of most crops are relatively insensitive to water rates, with the result that there is little incentive for irrigators to use water sparingly. The solution to the problem is that water rates must be raised as a spur to the achievement of higher efficiency through the better use of all the factors at stake. Where water to a much greater extent than soil, is the limiting factor for irrigation schemes, and likely always to be far more so than soil, it is essential that irrigation farmers pay much more attention to the yield per unit of the scarce factor through the optimal combination of both associated factors. It is only by prescribing realistic prices to both resources—prices that reflect the scarcity value in the national economy—that this objective can be achieved.

In general, therefore, it is regarded as fully justifiable gradually to raise water rates at existing schemes till at least the annual operating and maintenance costs are covered, and that for all new schemes this approach be adopted from commencement. In so far as possible, a contribution must also be made towards overhead expenditure.

(24) *Transference of water from regions of surplus to regions of shortage*

The provision of adequate water will in future be not only a national problem but to an even greater extent also a regional problem. The planning of catchments as geographic units will be demanded as well as the appropriate linkages of the resources of contiguous basins.

The basic aim in formulating plans for individual catchments and their mutual coupling should be the establishment of a broad directive for the optimum use, or combination of uses, of the water resources with provision for the future needs of the region.

There is, in the Republic, fortunately no legal restrictions for the transfer of water from one river basin to another. This does not, however, relieve the authorities concerned with such transfers of the responsibility for preparing very careful cost-benefit comparisons, not only in the region of origin but also in the water-receiving region.

The solution of our water problems will in future entail the conveyance of more and more water over longer and longer distances. To provide for our large metropolitan regions, and some of our new industrial nodes and irrigation projects, the linking of neighbouring catchments will be an essential requirement. This demands the thorough planning of our water resources to ensure that optimum benefits will accrue to the whole country. In applying this policy, socio-economic principles that embrace the interests of the country as a whole rather than the mere sentimental or geographical considerations must be decisive.

(25) *Capital expenditure on the development of our water resources*

Maintenance of a balance between supply and demand will in future call for huge and steadily increasing capital expenditures. Spending of funds for the development of our water resources has in fact been increasing sharply over the past years and the trend will no doubt persist. The reasons for this are to be found, first, in the industrialisation of the South African economy and the concomitant urbanisation of the population, secondly, in the fact that the more accessible and less expensive schemes have already been completed and, thirdly, in that water will in future have to be conveyed over steadily increasing distances. According to estimates, at present prices, the annual capital expenditure by the State on the development of our water resources will rise from R100 million during the 1970's to R200 million during the eighties and to R410 million by the end of the century. For the local and regional distribution of water, local authorities will have to incur appreciable additional capital outlays amounting by the close of the century to R125 million per annum.

III. Policy Issues

(26) *Planned development of the Republic's water supplies*

The objective of planning is to achieve the optimal development and use of the country's water resources and this requires co-ordination with general economic and physical planning. Planning is thus an interdisciplinary process and a never-ending task.

In the past our water resources have been developed largely on an *ad hoc* basis—projects were designed and executed to meet clearly established immediate needs but with an inadequate rational basis for the determination of priorities, and the optimal scale and sequence of development projects. Information provided in White Papers is usually aimed at justifying a particular scheme but is inadequate from the point of view of the cost-benefit analysis of projects generally. Frequently also the proposals are based on inadequate preliminary physical and economic investigations and analyses. The result is that the right scheme is not always tackled at the right time.

Planning of our water resources must be thorough, however, not only because of the importance of providing adequate supplies to maintain life and for the advancement of the people, but also because of the enormous capital expenditure required for major water schemes.

For the effective utilisation of our limited resources proper socio-economic evaluations of projects are indispensable. These require careful weighing of all the benefits—direct as well as indirect and intangible—against the associated costs. Only in this way can it be assured that, with the many other investments competing for the scarce financial and other productive resources of the land, a given project can be socio-economically justified.

Co-ordination of water development with general economic development is especially imperative to ensure that the scarce water resources are effectually exploited to provide for the future needs of the various sectors of the national economy.

Till now our water resources have been developed primarily for irrigation purposes. Because of the continually rising proportional contribution of manufacturing industry to employment and to the gross national product, the Commission is convinced that justifiable industrial development and the resultant future urbanisation of the population must be promoted by the fair apportionment of water among all sectors of the economy. In future allocations of water to irrigation development the same socio-economic considerations must apply as hold for the other sectors. Of the available supplies at the big schemes—the Orange and Pongola—a substantial share must also be reserved for industrial and urban development.

Neither on economic nor on strategic grounds is there any urgent need for the large-scale provision of additional water for irrigation within the foreseeable future. Emphasis should far rather be placed on raising the productivity of agriculture and animal husbandry on the already available dryland and irrigation soils and