WATER RESEARCH FOUNDATION OF AUSTRALIA

REPORT No. 40

THE CHANGE AND CHALLENGE OF OUR ARID LANDS

P R E F A C E.

The Change and Challenge of our Arid Lands was a joint symposium arranged by the S.A. State Committee of the Water Research Foundation and the Department of Adult Education at the the University of Adelaide. The symposium attempted a critical and authoritative look at the challenges and opportunities for balanced development of the arid lands. Within this framework it also examined important environmental matters, the potential for tourism and natural resource development, the future of agriculture and the need for national parks. The organisers felt that it made some contribution to informed opinion as to the realistic physical and economic development of arid Australia.

There was some criticism at the symposium of the limited reference made to the Aboriginal people. This was a conscious decision of the organising committee. It is a subject that at this time generates more heat than light and the committee felt that the problem is a universal human one, not necessarily tied up with arid land development.

The symposium was given an international flavour by the presence of two overseas visitors. Dr. Thadis W. Box, Dean of the College of Natural Resources, Utah State University and formerly Director, The International Centre for Arid and Semi Arid Land Studies, Texas Technological University, delivered the keynote address in a public lecture and Professor Keith Campbell and he gave the review papers at the end of the conference. The visit of Dr. Box was made possible by gifts from various organisations and firms whose assistance is acknowledged elsewhere.

The second visitor was Dr. N.N. Drozdov of Moscow State University, a visiting scholar at A.N.U. who delivered his paper on comparable problems in the U.S.S.R. at short notice.

It is worthwhile at this time to reflect on the debt owed to the authors of papers and the organisations which support them. There are many conferences held all over Australia supported in this way and these are an important contribution to the educational scheme and the dissemination of knowledge. The papers which follow are a record of such a successful conference and a reference source for knowledge in the areas dealt with at the symposium.

I should also like to record my thanks to the S,A. State Committee members - especially Mr. J.V. Mertin and to Dr. Derek Whitelock of the Adelaide University whose Department carried much of the burden of the organisation.

W. S. Boundy
Hon. Sec.
W.R.F.A. (S.A. Committee)
School of Physics
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WATER RESEARCH FOUNDATION OF AUSTRALIA

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This Report is the fortieth of a series dealing with interesting and informative subjects associated with water conservation, use and control, issued by the Water Research Foundation of Australia.

The opinions expressed by the Authors of the included papers are not necessarily endorsed by the Foundation which however believes the subjects covered have been approached pairly and in an objective manner.

Any correspondence in connection with this Report should be addressed to the Honorary Secretary.

F.R. BARNETT

Hon. Secretary
P.O. Box 47, Kingsford,
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May, 1973.

WATER RESEARCH FOUNDATION OF AUSTRALIA

(South Australian State Committee)

A Symposium

THE CHANGE AND CHALLENGE OF OUR ARID LANDS

REPORT NO. 40

DEPARTMENT OF ADULT EDUCATION,
THE UNIVERSITY OF ADELAIDE.

University of Adelaide,
February 23 - 25, 1972.

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"THE CHANGE AND CHALLENGE OF OUR ARID LANDS"

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WATER RESEARCH FOUNDATION OFAUSTRALIA
(S.A. STATE COMMITTEE)

DEPARTMENT OF ADULT EDUCATION
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CONTENTS

CONTENTS

ACHIEVING THE POTENTIAL OF ARID LANDS

Thadis W. Box

Water is not evenly distributed across the face of the globe. Somewhere between one-third and one-half of the earth's surface experiences drought during the year, and these dry lands are the subject of this conference. The exact amount of the earth's surface classified as arid or semi-arid will vary, depending upon the scholar and the source. Meigs (1953) used climatological indices and calculated that approximately one-third of the earth's surface falls into the category of arid or semi-arid. If biological criteria are applied, as has been suggested by Perry (1967), then a much greater amount of the earth's surface can be put into the arid category. Lands called "arid" vary all the way from true deserts, such as those described by Mc Ginness (1968), to the monsoonal tropics, which receive rather large amounts of water but are extremely dry for over half the year.

For the most part, these dry lands of the world are forgotten lands. On each continent they were the last to be settled, and in many cases they still have not been occupied by continuous human habitation. People come into them only when they are drawn by adventure or promise of economic gain. Most commonly it is the promise of mineral riches that bring people into the areas. The oil fields of Arabia and North Africa have caused settlements to spring up in the deserts, and more recently the nickel and iron deposits in Western Australia have contributed to the development of towns and seaports.

But for the most part, the arid regions of the world lead only to a subsistence, pastoral economy with men and their animals living as part of nature and being subject to the ecological constraints of the area in which they live. In the developed and industrialized nations of the world, such as Australia, the United States, and Argentina, the dry lands have been exploited for animal products. Huge pastoral industries developed early in the lives of these countries as fortunes were made from mining the vegetative resource in the arid regions. In most cases this exploitation or mining of the vegetative resource has left a depleted and degraded environment that will not heal itself through normal secondary successions in the lifetime of a man.

Today there are few areas of arid regions that have not been occupied or exploited by human animals. Those that remain are held in their pristine condition due primarily to lack of surface water. Thus, we have a small portion of the world's arid zone unoccupied because of water restrictions or economics and a larger portion in various stages of degradation brought on by past use. To some these arid regions of the world are valuable simply to hold the world together. I maintain that they have a potential to contribute to society if they are properly managed.

The potential of the arid regions of the world depends primarily upon human population pressures. Given a stable population, these lands will probably continue to produce limited animal products on a sustained yield basis. This statement presupposes that we apply our knowledge of arid ecosystems and continue to develop new knowledge that will prevent the mining of the vegatative area that I mentioned earlier.

I think an even bigger contribution than that of animal products may be the arid regions' contribution to open space. Heathcote (1969) has suggested that the emptiness of the arid lands of Australia may be their most important resource. I suggest that the same thing can be said for most of the arid regions of the world.

The emptiness and open space of arid lands may have some value for waste disposal. It is the largest reservoir of air available for dilution of industrial waste. It represents a sizeable area for solid waste disposal, and it has even been suggested as an area where radio-active waste could be disposed. Personally, I do not want the arid areas to become the humid regions garbage dump.

Perhaps the most important contribution of the open space characteristic of arid lands is for recreation. Many of the dry regions of the world have exceptional scenic and aesthetic appeal. Many of the great national parks in the United States are in the desert regions. Such areas as the Grand Canyon, Arches and Bryce Canyon National Parks attract millions of visitors each year, and thriving cities and towns are supported by people visiting these areas. Australia's centre offers equally fascinating tourist sites. The huge monolith in the middle of the desert, Ayers Rock, is known throughout the world. The sheer beauty of the red sandstone cliffs and the white ghost gum trees are unmatched anywhere in the world.

If the human population were stabilized today, the arid lands could look for a slow but steady increase in importance, due primarily to the recreational value of these lands. However, I suspect that the human population will not be stabilized in the near future. Although I am optimistic that we can slow down the rate of growth somewhat, I think we can look forward to more people in the future. These people will make more demands on the arid regions of the world.

Although it is difficult to imagine in a time of agricultural surpluses and green revolutions, widespread food shortages may exist as the population increases. One of the first reactions of people when faced with a food shortage is to put more land into cultivation. If we examine the world's available resources, the two major areas appear logical for expansion of agriculture. These are the tropical rain forests and the arid lands of the world.

The tropical rain forest are blessed with adequate amounts of water, but their laterite soils are not conducive to intensive agriculture with today's technology. Barring a major break-through in soil physics and chemistry, these lands will not contribute greatly to the world's food supply.

The arid regions of the world, on the other hand, have adequate supplies of energy and generally have fertile soils suitable for crop production. The problems of developing a water supply in arid zones have been discussed adequately by Stephen Hancock in this Symposium. However, I would like to direct his thoughts to the problem of increasing food production.

One of the first considerations in obtaining water for arid regions appears to be the use of water from surface flow. However, if we carefully examine the earth's resources, most of the water from rivers flowing through arid regions is already claimed and is being used either for agricultural or industrial purposes. There are a few regions left, such as the quarter of a million hectares between the Guiba and Shebeli Rivers in East Africa, but for the most part the land that can be irrigated from rivers is small and limited in size.

Dams have been constructed on most rivers suitable for supplying irrigation water. Technological man is seldom daunted by such a condition as one where the rivers running through the arid regions are already in use. The world of science fiction is no longer in the future. We can easily change rivers and divert them into the arid regions of the world. One of the most successful of these schemes is the Snowy River Project that diverts waters from the eastern slope of the Australian mountains to the centre of New South Wales. Large and more grandiose schemes are proposed on almost every continent of the world. An example of this is the North American Water and Power Alliance Project proposed for North America. This scheme would bring waters from Alaska and Canada through a series of tunnels and dams to the Great Plains Region of the United States, the intermountain desert, and part of northern Mexico.

Such vast projects as NAWAPA are within the realm of engineering feasibility. Only a few years ago they were being seriously discussed in many of the states of the western United States. Today, with our concern for environmental issues, most of these projects have been tabled. A recent study (Thomas and Box,1969) showed that most of these major water transfer schemes were based on economic and engineering feasibility and not on ecological consequences. When the ecological trade-offs are considered, many of these projects which seem reasonable on the surface become unacceptable to today's society. I doubt that we will see other large scale projects seriously proposed in the next decade. However, if the human population grows to the point where famine is widespread, such drastic measures may again be considered for the development of arid lands.

Long before such grandiose schemes as the water import systems discussed above are put into effect, we may return to water harvesting methods that will allow water falling in arid regions to be used more efficiently. Most of the traditional primitive cultures of agricultural people who inhabit dry lands have some form of flash flood irrigation for agriculture. These may involve planting seeds in flood plains where additional water runs on, diverting water from hillsides to artificially flood an area, or other primitive technology. Today modern agricultural engineers are capitalizing on these traditional forms of water supplementation and creating systems where agricultural crops can be grown using water that falls in an area. A good example of one of these systems is represented by the work of Johnston and Vandoren (1969) at Bushland, Texas. By keeping two-thirds of an area bare to be used as a watershed to catch water for the other third, total productivity of crops is increased.

Another major source of water for the arid regions is the underground water supply. Although precipitation is limited, there are many areas that contain sizeable basins of water from both current recharge and geologic periods. The largest single area of irrigated agriculture in the world occurs in the High Plains area of Texas. It is supported entirely on water of Pleistocene origin. This water is being mined, since re-charge cannot possibly keep up with the drawn-down from the pumps. The basin and range portion of the western United States has many smaller basins that contain a mixture of geologic water and water from current recharge. Most of these with suitable water quality have been developed.

Much of central and western Australia is not unlike the basin and range portion of the western United States. The major difference is that the Australian underground water has not been exploited as heavily. Vast areas such as the Mereenie formation of the Amadeus basis may hold up to 1,000 million acre feet of stored water. The depth of the water and the distance from available markets make immediate exploitation unlikely. However, a change in the demand for foodstuffs or luxury items that could be produced in the Centre could easily make this and other basins of stored water attractive for investment. Many smaller basins exist throughout Western Australia. The work by the Western Australian Department of Agriculture at Wiluna has shown that many citrus crops and vegetable plants can be grown there. Again, only time will tell whether irrigated agriculture will be economically viable business. For the most part, areas with underground water in arid regions are limited in size, expensive to develop, and suffering from all sorts of market difficulties.

Another hope held out for arid lands is the development of weather modification schemes that will bring moisture from the clouds. Large scale weather modification projects do not appear likely since the very synoptic conditions that cause the area to be dry in the first place usually prevent clouds from passing over them.

Smaller closed systems with the weather modified within greenhouses and plastic enclosed areas appear to be more practical at the present time. Systems such as the one described by Torres and Hodges (1969) may offer some promise for growing crops in the arid regions of the world.

Even with great advances made in the technology of water management, the major portion of the arid lands will always be water deficient. These lands will not produce many crops suitable for direct consumption by human beings. The plants that grow on arid lands will continue to be harvested by animals. These lands, then, will be used primarily for the production of protein in the form of red meat (MacFarlane, 1968). These meat products will likely be a luxury item and may not come from traditional cattle and sheep (Box, 1972). Work done by MacFarlane and his associates indicates that there are many animals that may be better suited for arid regions than the traditional cattle and sheep. Camels, goats, donkeys, and many of the wild ungulates of Africa are much more efficient in their utilization of water and the rough forages of arid regions.

There is adequate research data available now to indicate that animals other than cattle and sheep may be biologically more efficient, but they are not sociologically or culturally acceptable. The housewife in an industrialized society does not want to cook a meal consisting of donkey sandwiches or kangaroo rat stew. A good example of the effect of consumer preference on the utilization of rangelands is the case of goats. The goat, although much maligned by foresters in the western world, is an extremely efficient animal in arid regions and can actually be used to improve rangelands (Merrill and Young, 1954). Heavy grazing by cattle and sheep has forced many of the Texas rangelands into a vegetation dominated by dense growth of bush. Goats, properly stocked on these lands, make good yields of protein and at the same time control the plants viewed as noxious by the cattle rancher. However, with the exception of a small area along the Mexican border, goats are not considered a desirable food source by most Americans and are looked upon as downright inedible by many. Therefore, due to a lack of a ready market for goats, the production of a valuable protein source is lost and Texas ranges continue to deteriorate. These same animals that are not desirable in the American culture bring premium prices in the Arabian market.

Although I suspect there will be some major changes in the use of the arid regions for animal production, I predict that in the future these arid regions will become more important as a protein producing source than they are today. Some of the major changes are likely to be :

1. Meat will be produced directly from native plants. Little or no feeding of grain in the forms of organized feedlots will occur. Grain will be consumed directly by human beings.

2. Meat will come from new forms of livestock. There is no reason why meat from donkeys, goats, and other more efficient animals of arid regions cannot be used for human food. In the day of modern advertising and Skinnerian psychologists, human behaviour can be easily modified.

3. Red meat will become a luxury item. Many housewives in Europe and America consider meat a luxury today. As people generally shift toward diets with more plant protein, meat will become more and more of a luxury and the pastoralists who use the arid lands will be catering to a market that is much the same as that of the lobster fisherman today.

If the role of the arid lands in food production is to be relegated to the production of luxury items with a growing human population, then other sources of usefulness of these arid regions will come into their own. Perhaps the most important use of the arid regions will be for the production of recreational experiences. Although there are many areas of unique beauty in the arid regions of the world, space will be the biggest asset. Today we are seeing a great exodus from the crowded urban areas to the open spaces of the United States. Many of the desert regions in California, Utah and Nevada that were once considered inhospitable and passed through as quickly as possible now have literally thousands of picnickers, hikers, and motorbike riders visiting them every weekend. This phenomenon is likely to continue in most of the arid regions of the world. As the cities become more crowded, some people will simply adapt to the city conditions and fear open space. Others, though, will demand to get out and enjoy the emptiness of the arid areas.

There will be several different kinds of demands on the arid regions. Some people will simply want to get away from city conditions, but at the same time will demand parks, nature trails, caravan facilities, and other developments. This group of people will cause a need for a large number of services that are not now available in arid regions.

Another type of recreation user will be looking for a solitude experience. In the United States we are seeing a great increase in people who use the wildernesses, the desert primitive areas, and other undeveloped sites. These backpackers may spend several weeks camping away from civilization and hiking literally hundred of miles in search of solitude. Their equipment, though light and extremely portable, is expensive and the basis of a whole new industry in the sporting world.

Arid Australia has only scratched the surface in capitalizing on the recreational facilities available in its arid regions. Mr. Gluyas has discussed the potential for tourism in this Symposium. While most Australians tend to think of the Centre as an area that will produce tourist dollars from overseas, I think Mr. Gluyas' comment that the real potential lies in the Australian population should be carefully considered. Australians have traditionally looked to the sea for their recreation and for their holidays. The arid regions offer a new challenge. The development of minimal facilities might completely change the holiday pattern of many Australians.

While I consider the potential of arid lands to lie primarily in the area of recreation and food production, it cannot be denied that the air above these areas is one of the important world resources. Oxygen is produced by the desert shrubs and the space above the arid land looms as one of the largest dilution reservoirs available to the world.

I think it is inevitable that the arid lands of the world will develop as the human population grows, but they will develop more slowly than the humid regions of the world because of restrictions. These restrictions are both ecological and sociological.

The climate is one of the main deterrents to the development of arid regions. Not only is the total amount of precipitation of the arid regions low, but it is generally undependable and variable in its distribution.

This variability is both seasonal and spatial. In most of the arid regions of the world the number of years with below average rainfall far exceeds that of above average rainfall. Drought is common (Heathcote, 1969). Likewise, the spatial distribution is not good. Flash floods may inundate a small area in a desert while only a few kilometers away no rain falls at all.

These climatic fluctuations lead to some rather severe biological constraints to the development of arid regions. The low rainfall leads to a low production of biomass. The variable distribution creates a situation where productivity of forage is undependable and highly variable. A three hundred percent variation in forage production between high and low years is not uncommon in most arid regions of the world.

The plants of the arid regions have evolved modifications for survival rather than for production. Such modifications as thorns, hairy leaf surfaces, stiff rolled leaves, etc. may make for water efficiency, but are not the most desirable characteristics for a forage plant. Indeed, these plant modifications may dictate the kinds of animals that can be raised. For instance, the mouth and tongue morphology of camels and goats is far more adaptable to eating the desert vegetation than those of cattle. The physiology of desert animals also indicates that this rough forage can be used by many animals better than the traditional European livestock.

The sporadic patterns of rainfall and vegetation production almost dictate that the dry regions of the world be grazed with nomadic grazing patterns. Most of the traditional pastoral cultures of the dry regions of the world are based on nomadism. The countries of North Africa, the Middle East, and East Africa all depend upon the shifting of people and livestock to favourable conditions. In the developed countries of the world, livestock men of European origin first tried to use the dry regions under a set stocking pattern. Those that survived retreated into some form of neo-nomadism. For instance, in the western region of the United States livestock are seldom kept on the same range year round. In Utah our sheep flocks winter on the desert ranges at the centre of the Great Basin. They graze in the spring and fall in the foothills of the mountains and summer in the high rugged mountains of our State.

Here in South Australia, one of your most renowned pastoralists, Peter Waite, early recognised the need of having enough land to shift his livestock. He stoutly maintained that small properties could not survive in South Australia, but that the properties should be large enough to allow moving of livestock from one area to another. Experience in the past hundred years has certainly proved Mr. Waite correct.

In addition to the climatic and biological restraints placed on the development of arid lands, social constraints control how the dry regions are used. For the most part, the arid regions of the world have a low population density. Political power is concentrated in the cities. Public funds expended for the development of the arid regions have a low-priority because the needs of the city dwellers must be met first. Australia can serve as a good example of these social constraints. Here the arid region covers about three-fourths of the continent. The area supports about one-third of the flocks and herds, but only about two percent of the people (Perry, 1969). One cannot expect an elected Parliament to expend a large amount of public funds on an area occupied by only two percent of the people.

Support and service facilities in arid lands are usually poor, or, in the case of developing countries, lacking entirely. Communication is difficult at best and impossible in some situations. Transport, if available at all, is extremely expensive. Education and health facilities are minimal to non-existent.

The people living in these arid regions of the world tend to become self-sufficient and individualistic. They act on their own initiative with little or no collective effort. Social institutions are weak and the political power of the people tends to be fragmented and ineffective. Therefore, almost without exception, development dollars have not been available for the arid regions. Research efforts have been scattered and poorly funded.

Economic restrictions do not stop with the low availability of public funds. Any enterprise going into an arid region is usually a high risk, low return business. Standard financial institutions are not anxious to support such efforts. For the most part, neither financial institutions nor special systems of finance are available for arid lands.

Regardless of the restrictions that are limiting the development of arid lands, the dry portions of the world loom important in the destiny of mankind. Only a few years ago the cry was for the development of these lands. Now, there seems to be a general priority for conservation and keeping them in pristine condition rather than for development. Regardless of which route is taken - that of development or that of preservation - several things are essential for their use.

The first is that the future of arid lands must be established as a high priority item with the people in political power of whatever nation is involved. Most likely the seat of this political power does not reside in the arid region. The major exceptions may be in areas where the entire country is arid, such as Israel or Somalia. If a plea is to be made to the political power located outside the arid region, it must be made on one of two bases. First, we must clearly show how we can increase productivity for the good of those people living outside the arid area; or, two, we must show where the conservation of an unspoiled area leaves something of value for them.

The second major need in arid lands is for adequate research to understand the arid ecosystem. For the most part, country-originated research has been fragmented and poorly funded. One major effort to understand the dry regions of the world comes through the International Biological Program in its Desert Biome Project. This program seeks to coordinate all of the ecological information on the world's deserts into one major data bank to make it available to other workers throughout the world. Australia and most other countries of the world are participating in this world-wide event.

The United States effort in the Desert Biome is headquartered on our campus at Utah State University. We receive a grant of about U.S. $1,300,000 annually from the National Science Foundation to undertake ecological studies in desert regions. Much of the effort is farmed out to some 36 western United States Universities. The major effort on our campus is to construct a computer model that will simulate the workings of a desert ecosystem and predict the consequences of the manipulation of any part of the system. We have sites set up in the cold desert region to collect real world data that will be fed into the model in order to validate it and check its accuracy of prediction. In the other 35 universities involved, we have a series of process studies designed to gather information on biological processes within the ecosystem . The ultimate aim is to pull all of these processes in and test our model with them. Similar studies are going on here in Australia, in Israel, in India and other parts of the world.

We hope that this effort in the Desert Biome will allow us to better understand the workings of the desert ecosystems. In addition to biological research, socio-economic research should be initiated that will relate the needs of society to the biological realities of desert conditions.

The third major need for the use of arid lands is for money and trained personnel for the application of the research data once it has been generated. Both may have to come from the humid areas.

Australia has often been described as the world's driest continent. Most Australian scientists realise that these needs and constraints I have discussed above apply directly to this continent more than most. I have mentioned earlier that three-fourths of Australia is arid, yet only two per cent of the population resides in the area. It should be clear, then, that the future of arid Australia lies not in what happens within the arid zone, but mainly in what happens outside the arid region. The future of Australia's arid zone is highly dependent upon world population growth, world markets, and the world economy, but its real destiny lies within the minds of the Australian public. If it is their desire to have a useful and productive resource from their arid area, it is within their power. If they choose to ignore it, it may become just another large desert with the primary usefulness of holding the world together.

I do not want to take an alarmist's view and maintain that Australia's arid lands will develop into a large, useless, Sahara-type desert within this generation. However, it is inevitable that the production from Australia's arid lands will be continually lowered if current land use practices are followed. It is not a question of whether production will be lowered if current practices are continued, but when they will be lowered.

History has demonstrated on every continent of the world that the continued heavy stocking through good years and bad lowers the productivity of a range resource. Australia is no exception.

It is inconceivable to me that Australians will not choose to develop or protect their arid zone. In fact, important steps have already taken place to demonstrate that they desire to place more emphasis on the arid portion of their continent. CSIRO has established a Rangelands Research Unit with special mission to conduct research in the arid areas. A major symposium was held in 1969 by the Australian Academy of Science (Slatyer and Perry, 1969) to look at the needs of the arid region; and this Symposium here demonstrates that the need is recognised, at least by the scientific community.

As I indicated earlier, the future of Australia's dry lands depends on Australians' continuing to believe that these arid regions are important. If they do this, then the future for Australia's dry lands is very bright indeed. There is no denying that there is much land left in the humid zone that needs to be developed, but it would be short-sighted to write off three-quarters of the country for the development of a small part that is in the favourable rainfall areas. Therefore, Australians must be willing to spend money on research, natural resource management, and administration of arid areas without expecting significant returns in the short term. However, such an investment in research on arid lands could well pay large dividends in the long haul.

Australia is a vast country with numerous possibilities in all sectors. Any capital or people available for development can find ample opportunities in the humid regions where the amenities of life are more easily available and returns on capital more apparent. Therefore, if Australia's arid zones are to be developed, governmental policies must be such that they will encourage outside risk capital and immigration to consider the opportunities of the arid zone. The needs of Australia's arid region are many. It is unlikely that money will be made available for solving all these needs at once. Indeed, even if funds were available, manpower is not available or adequately trained to take on the task. Therefore, some priorities must be established in the needs for Australia's arid lands.

First on the list of priorities must be the stopping of the present deterioration in productivity of the arid zone. I am not advocating the removal of livestock and the establishment of large reserves or the entire area as a huge arid zone park as is suggested by Mr. Cashmore in this Symposium.

Research in the other arid regions of the world indicates that deterioration of rangeland can be halted and, indeed, some improvement made provided proper grazing management is effected on the dry lands. This management must be based on the physiology of the individual plants and the animals using the range and the overall ecology of the range resource. Therefore, immediate action programs are needed with incentives for light stocking, pasture rotation, and other practices that have given results in limited areas.

Coupled with this recommendation is the immediate need for research on ecology, physiology, slimatology, etc., to provide information for the designing of more efficient management practices that will allow some improvement in the productivity of arid rangelands. This research effort should have an equal priority with that of stopping the deterioration that is taking place. Indeed, they are interrelated. Without research information on the processes of the Australian deserts it is doubtful that foreign technology can be applied directly to the Australian situation.

There is no doubt that the productivity of Australia's arid rangelands can be improved, provided management is based upon a clear understanding of the ecological processes of secondary succession. However, these processes are not well known. Research must be conducted into the life histories of plants, the behaviour and nutrition of animals, and the population dynamics of plant communities before large scale management schemes can be developed for strictly Australian conditions.

A third priority for Australia's arid lands is the development of its underground water resources. The first step in this must be the determination of a quantity and quality of water available. Some estimate of the length of time this water will last under the various rates of development is needed. Agronomic research on the types of crops best able to exploit the limited resource is needed. Work on the possible integration of irrigated agriculture with the already established grazing industry of the arid region is most promising.

Finally, laws and regulations are needed to protect the water resources from industrial and agricultural exploitation where they are needed for human habitation on recreational use. I agree with some of Mr. Hancock's statements earlier in this Symposium involving the mining of a water resource. Water mining is a legitimate use of a natural resource, but it should be permitted only after planning studies have indicated all possible uses to which the water can be put and listed these uses in some sort of a national or regional priorities.

A fourth priority is the development of the recreational potential of the remote regions of Australia. Camping facilities, caravan parks, self-guided nature trails, and other facilities are needed if these dry regions are to make their proper contribution to recreation and tourism. An improvement in the tourist accommodations is a need if Australia's arid lands are to compete with other internationally known tourist attractions. Today's modern tourist likes to think he is roughing it, but he prefers to rough it in air-conditioned facilities complete with swimming pool, modern bar, restaurants and nightclubs available. The country pub, although colourful and in most cases comfortable, is not likely to attract the really big-spending foreign tourist. Dude ranches, complete with all modern facilities, offer great promise in Australia's outback.

Another need that must have a rather high priority in the development of arid zones is the building of living facilities for the residents of the dry areas. Cities such as Alice Springs have all the climatic potential for becoming major retirement areas for people in Australia and other countries. Cities such as Tucson and Phoenix in the United States have little to offer except a warm climate and beautiful scenery. It is entirely possible that a heavy demand will develop for winter homes and retirement cottages in the Alice Springs area. Australia's arid zone, unlike so many of the other arid regions of the world, is reasonably productive pastoral country.

It has a cover of trees and shrubs and scenery of sufficient quality to attract people to live in the area. It is presently an important part of the pastoral economy of Australia. There is every reason to believe that its importance in both national and international circles will become increasingly more important. The potential for greatness is there. It is up to the people to develop that potential.

I had the pleasure of attending the Arid Land Symposium sponsored by The Australian Academy of Science three years ago. I think I have noticed several major changes, at least in the scientific community, during these three years. At the Canberra symposium, the major emphasis seemed to be on development of the arid region. Almost every paper tended to stress someway in which productivity could be increased or development enhanced. This Symposium has tended more toward the protection and preservation of Australia's arid lands. This observation may not be valid, and if my observation indeed is correct, it simply may be a sign of the times. When I was last in Australia, the immigration policies were geared to bring in more people at a more rapid rate. Today many more Australians are asking the question, "Why should Australia increase its population and what have we to gain by large numbers of people".

This attitude toward improving the quality of life rather than the quantity of experience appears to me to be a worldwide movement. In America we have had three major environmental movements. The first occurred near the end of the last century after we had settled all of our productive land. Led by President Theodore Roosevelt and Secretary, Gifford Pinchot, it resulted in the establishment of national parks and national forests. It was clearly based on saving some portions of the unspoiled environment.

The second major movement occurred during the 1930's following a period of settlement of marginal lands. Huge dust storms developed because of a land use policy that was ecologically unsound. The U.S. Soil conservation Service was established and much of the land restored to its original productivity. This second movement was reclamation based.

We are now in the midst of our third major environmental movement. This movement, unlike the others, is not based on preservation or reclamation of land but the survival of the human animal. In pursuit of the luxuries of life, we have equated consumer goods with a high quality experience and found ourselves living in crowded, smog-encased cities and caught up in an industrialised society that has not actually increased our quality of experience. Our arid regions are fast becoming filled with resort cities such as Tucson, Phoenix and Las Vegas. Huge, coal-burning power plants designed to supply electricity for the populated West Coast area, fill the air with smoke and cinders. I think it is healthy that Australians take a good hard look at the situation in which America finds itself.

But if no action is taken following this Symposium, we have simply gone through an academic exercise of talking to ourselves about problems that are important to one third of the world that has little political muscle to help itself.

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THE ARID ECOSYSTEM

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At a general level, arid ecosystems have much in common with any other non-urban terrestrial system in that all are climate/land/plant/animal/decomposer systems. That is, they are all complex systems in which a number of factors such as climate, soils, plants, and animals are interlinked by a series of processes such as infiltration, transpiration, photosynthesis, grazing, decomposition, and erosion. The important distinguishing feature of arid ecosystems is low or erratic rainfall (or both), although a number of secondary characteristics follow from this lack of rain. It is the effectiveness of rain rather than any absolute amount which distinguishes arid from non-arid systems. (Perry, 1970a).

An important point is that there is not one but many arid ecosystems. The vast arid area of Australia has a wide range of climate, rocks, topography, geomorphology, soils, plants, etc., and all the combinations of these constitute distinct ecosystems with different productivity and stability characteristics. Arid Australia is much bigger than, and just as diverse as, the coastal strip from Cairns to Adelaide. From a use of management point of view each of the different ecosystems needs to be considered separately. However, the main purpose of this paper is to discuss their general characteristics.

Many of the general features can be illustrated by a very simple diagram (Fig.1) with four main compartments or stores. These are -

1. Soil or land which is the basic resource in that it provides the nutrients and the water store needed for plant growth.

2. Plants which provide forage and shelter for animals and a physical barrier to erosive forces on the land surface.

3. Animals, including domestic stock, wildlife and feral animals, and invertebrates, all of which depend on plant material for survival, growth, and reproduction and whose excreta and dead bodies are food for decomposers.

4. Plant and animal detritus and the decomposer organisms on which the recycling of nutrients depends and which are responsible for the maintenance of the physical condition and chemical fertility of the soil.

The main inputs or driving forces of the system are solar energy, wind and rain. In some parts of the world man harvests plant products but in Australia the main outputs from the system are animals (or animal products) and erosion products.

WATER

Water is of tremendous importance in arid ecosystems. The availability of soil water after rains brings the system to life and, on the other hand, runoff water can be a powerful erosion agent. (Fig.2). In general water only enters the system as rainfall although its subsequent spatial redistribution is very important to the productivity of many individual ecosystems.

Rainfall is partitioned at the exposed surface of the ecosystem into three components (Fig. 3.)

1. Interception. - This is water which wets the surface of vegetation, litter, and soil (to a depth of about 2 or 3 cm) and is lost from the system by direct evaporation within a short time. Depending on the nature of the surface and the season of year the amount of interception on any day is within the range of about 2 to 5 mm. With large falls this is insignificant but because it accounts for all, or a high proportion of, rain from small falls (of which there are many) total interception losses probably average about a third of annual rainfall. For example, at Alice Springs an average interception of only 2 mm on each of the nearly 40 wet days would amount to about a third of the 250 mm mean annual rainfall. The proportion of rainfall lost to interception is highest in dry years, i.e., years with few or no large falls.

2. Soil Water. - Rain in excess of interception is available for infiltration into the soil. The proportion which enters the soil depends on the amount and intensity of the rainfall in relation to the permeability or sorptivity of the soil and the capacity of the soil water store. In this respect the soil water store is like a container of fixed capacity with a perforated lid and a series of perforated partitions arranged horizontally throughout its depth. If rain intensity is greater than the rate at which it can enter the surface cover, or if the whole store, or the top part of the store, is full, then the excess runs off. Infiltration is increased by a good cover of plant material and litter creating a barrier to water movement and by a good organic matter content in the surface soil which makes for a higher infiltration rate. Sloping, bare, eroded surfaces take in little water and thus have little available for plant growth which means they tend to remain bare.

   The capacity of the soil moisture store varies with soil type and depth. Shallow soils and soils with hard-pans, e.g. "hard" mulga country may have capacity as low as 25 mm, with deep loamy or light clay mulga soils it is about 100 mm,

with deep heavy clay soils such as Mitchell grass country, it may be higher but these have very low infiltration rates and only the top 35 to 50 cm may ever become filled.

Water is extracted from the soil store by plants, the rate of extraction depending on evaporation rate, leaf area (possibly slightly modified by leaf morphology etc.), and the amount (or more accurately the tension) of water in the root zone. Initially extraction is slow but it increases as leaf area increases and then decreases as soil moisture tension increases (Fig. 4). Plant growth is roughly proportional to extraction rate and ceases when the store of available soil moisture is empty. From limited evidence the average extraction rate over the whole growing period is about 20 per cent of evaporation rate from a free water surface, at least in summer, but may be as high as 30 per cent in winter. (Everist & Moule, 1952, Fitzpatrick E.A., Slatyer, R.O. and Krishnan, A.I., 1967, Winkworth, R.E. 1970).

Both shallow and deep rooted plants, extract water from the upper (say 25 cm) of the soil store, water stored below this being only available to deep rooted plants. As extraction tends to proceed progressively downwards deep rooted plants (most perennials, some annuals) tend to have longer growing periods than shallow rooted plants (many annuals).

With any rainfall event, once the soil store in the rooting depth is filled, additional rain is lost to that site. Thus from any one rainfall event, no matter how large, plant growing periods can only be as long as it takes to empty the store. Soils with a small moisture store will therefore generally have low plant production. Plant growing periods are prolonged if follow-up rains replenish the soil store before it has been completely emptied. Such follow-up rains are not common in arid areas (cropping areas depend on successive rains to keep replenishing the soil store and so provide a continuous long growing period) but when they occur the results in terms of plant production are spectacular.

3. Runoff. - Rain in excess of interception plus infiltration runs off (or, on some surfaces, ponds and subsequently evaporates or infiltrates).

Runoff from any one area becomes runon to adjacent downslope areas where it either infiltrates, runs off, or becomes ponded on the surface. Redistribution of rainwater in runoff/runon systems occurs at all scales (microtopographic, local, regional, and larger) and is a very important factor in the productivity of many Australian arid zone ecosystems.

For example, each intergrove/grove unit in a groved mulga ecosystem is a closed runoff/runon system for all but large falls of rain. (Perry, 1970b). The bare intergrove acts as a catchment, the water from which is concentrated in the vegetated grove. The grove not only receives a disproportionate amount of water but, because of the concentrating effect, relatively small falls become effective and thus the frequency of plant growth is increased. Much of our saltbush and stony tableland landscapes and some Mitchell grass country have similar micro-runoff/runon systems. To the uninitiated the bare, scalded, sometimes pavemented, catchment parts of these systems are a result of overgrazing but they are, in fact, a natural feature on which the productivity of the system depends. Misguided attempts to reduce runoff and vegetate them will destroy the system. On the other hand overgrazing can destroy the vegetation on the runon part of the system in which case the whole landscape tends to become a bare runoff area.

At a larger scale the productivity of local and regional runon areas (floodouts, swamps, floodplains, etc.) depends on runoff from other systems but runoff going to saltlakes is wasted as far as plant production is concerned.

A very small proportion of runoff is captured and stored in natural or man-made waterholes for drinking water for larger animals, including man. Of this, only a small part is actually drunk, most is evaporated. Some runoff also goes into aquifers which can be tapped by wells or bores for the same purpose or for irrigation.

Notwithstanding the very great importance in our arid areas of the widespread natural runoff/runon systems (with associated natural erosion), one of the most drastic effects of grazing industries reducing vegetation cover has been through increasing runoff, and thus, reducing soil moisture and subsequent plant growth on runoff areas, and accelerated erosion.

VEGETATION.

The plant species assemblage on any arid ecosystem is determined by the climate and soils of the site but may be modified by selective grazing pressure. Hundreds of different plant communities occur in arid Australia but at a broad general level they can be grouped into four main types. (Christian, C.S., and Perry, R.A., 1969, Leigh, J.H., and Noble, J.C. 1969, Moore R.M. and Perry R.A., 1970, and Perry, R.A. 1970c). Spinifex communities occupy about half the area and remain virtually untouched by man. The other half, comprised of grasslands (e.g. Mitchell grass), low woodlands (e.g. mulga), and shrublands (saltbush and bluebush), has almost all been used for grazing domestic stock.

The amount of plant material produced in any growing period is largely determined by the amount of soil moisture available in the soil store and to a lesser extent by the mineral status of the soil. Both of these can be affected by feedbacks through the system because the amount of plant material left on previous occasions affects erosion rates which will be reflected in present ecosystem condition or status. Therefore, from the point of view of minimizing erosion, and therefore of the long term survival and health of the ecosystem, the really important aspect of vegetation is that a critical amount always be left standing.

Plant production occurs only during periods when water is available in the soil store. Because of infrequent rains and the limited size of the soil moisture store each growth period tends to be short and separated from the next by a long non-growth period. During the growth period some of the production is consumed (many invertebrates tend to be particularly active in such periods - consumption by larger animals is limited to about average because their populations do not change rapidly). However, at the end of each growth period the bulk of production is left standing as dead or inactive material. The fate of this material is as follows :-

1. Mechanical breakdown to litter. - There is a slow general rate of conversion of standing plant material to litter. The rate is increased in windy weather and greatly accelerated by ineffective falls of rain. Thus these ineffective (in terms of new growth) falls of rain not only do not produce plant growth but cause a loss of standing material. Physical contact by animals (e.g. trampling) also converts standing plant material to litter. The rainfall event which initiates the next growing period converts a considerable proportion of any residual standing dry material to litter.

2. Consumption by herbivores. - Standing vegetation provides a store of food material to support animals to the next growth period. Populations of many of the smaller, more sedentary animals tend to fluctuate with food supplies but populations of larger animals are less flexible and tend to be at a general level determined by forage produced in previous growth periods. If forage runs out, these larger animals either die or move to another ecosystem where forage is available.

3. Residue. - As mentioned above a residue of plant material is always required for landscape protection. New plant growth also comes from the residue - either from seeds or perennating buds. Ultimately (i.e. after subsequent growth periods) this residual material will become litter.

ANIMALS

Herbivorous animals consume many times their bodyweight of vegetation each year, most of which is excreted. It is the continuing demand for forage by herbivores that is potentially capable of damaging or destroying the vegetation. Their main role in the system is as part of the recycling process which would be very slow in their absence.

There is a tendency to think of the herbivorous animal component of our arid ecosystems being comprised only of domestic stock or perhaps domestic stock and kangaroos. In fact, the animal component consists of a very wide range of animals including invertebrates, small and large mammals, and birds, as well as domestic stock. Many have specialized feeding habits and must exert a considerable influence on the population dynamics and the growth and development of plant species. For example, some insects concentrate on such important plant organs as apical buds of grasses or on flowers, or seeds, of particular species. Many birds concentrate on seeds. Some ants collect large quantities of seeds and by storing them in particular places could reduce or enhance their germination chances. Termites harvest large quantities of grass and store it in their galleries. Their activities must have a considerable effect on the physical nature of the soil.

European man put additional animals into the area, including domestic stock, rabbits, and a number of other feral herbivores and also predators in the form of foxes and feral cats. These caused changes of varying degree in various ecosystems - changes in amount and type of forage, elimination of many natural waterholes but an overall big increase in density of watering points due to construction of tanks and bores, and new predators. The net effect on native fauna can be summed up as an increase in large marsupials and a great reduction or extinction of populations of smaller species.

The biomass of various types of animals varies with different ecosystems. In very general terms the average biomass of domestic stock is about 10 kg/ha on woodlands and shrublands, up to 30 kg/ha on Mitchell grass, and zero on most spinfex. The biomass of grass-eating termites and/or ants would be at least 10 kg/ha in woodlands, shrublands, and spinfex but is low on Mitchell grass. Marsupial bodyweight is probably in the order of 1 kg/ha in shrublands and woodlands and in some areas of spinifex but is very low on Mitchell grass and most spinifex. Rabbits fluctuate widely but are fairly restricted to woodland and shrubland country. Many invertebrates also fluctuate widely.

All these animals require plant material and water for survival growth, and reproduction. With most of the smaller ones, the population is adjusted to forage conditions, termites keep a store of forage and their populations probably fluctuate less. Domestic animal populations are maintained at fairly stable levels with sometimes increases in periods of forage plenty but usually with greater reductions in drought periods.

The invertebrates and many of the smaller animals obtain their water requirements from forage but larger animals need to drink, domestic stock generally more frequently than wildlife. Normally, adequate amounts of drinking water are available even during droughts, but animals which need to drink can only forage over that area around watering points that they can reach between drinks. The distribution of watering points thus determines the proportion of the area over which larger animals can forage.

The larger animals are mobile and, within the limits imposed by fences and distance from water, are able to select the areas on which they graze in accordance with their inherent behavioural characteristics and their preferences for food and shelter. This causes very uneven grazing pressure on different ecosystems. For example, in a 150 sq. km paddock near Alice Springs, Low (1972) has found that cattle exhibit a sequence of plant community preferences that change with forage availability. Although the average stocking rate is only about 3 cattle per sq km, one small preferred community had densities of up to 40 per sq. km. for short periods after rain, while cattle only entered a large area of mulga after long ory periods when little forage remained on the normally more preferred communities.

DECOMPOSERS AND NUTRIENT CYCLING

Decomposers recycle plant and animal detritus and are thus important in maintaining the chemical fertility and physical condition of the soil. Almost nothing is known of the organisms and processes involved or the factors which influence them but their activity is high only when the surface soil is wet and is very low at other times. Their activity will depend on an adequate supply of detritus on which to operate. Characteristically, soil organic matter is low in arid zone soils and is much lower in Australia than other arid soils of the world.

In an analysis of turnover in a saltbush ecosystem near Broken Hill, Charley and Cowling (1968) recorded the following distribution of organic material :

Above ground :			Kg/Ha
	Living :	leaf	825
		wood	1403
	Dead :	litter	148
Below ground :			
		roots	910
	Soil O.M.	(0-45cm)	37,949
Litter fall (1 year) :			
		leaf	684
		fruit	361
		wood	49

Above ground/below ground ratio:

Total organic material	6.3 per cent
Total N	0.9 per cent
Total P	0.1 per cent.

The figures are from only 1 year's results but probably indicate the general order of magnitude for the particular ecosystem. They show an annual litter fall greater than the standing leaf crop and very much greater than litter on the ground which indicates a very rapid litter breakdown. These figures, taken together with the above ground/below ground distribution of organic material, nitrogen and phosphorus, show that the system is one in which turnover is high despite the low biomass and the short periods of decomposer activity. It is also probable that the pool of available nutrients is small compared with the total reserve.

The decomposer organisms respond quickly to even small falls of rain, insufficient for vegetation response, and thus a series of discrete small falls of rain tends to generate a relatively large pool of available nutrients. This explains the general observation that good rains, following a series of ineffective falls, produce a dramatic response, whereas vegetation response in the second of two successive good years is poorer than that in the first.

The main store of nutrients in the system is in the soil. Under arid conditions leaching is minimal and characteristically nutrients are concentrated near the surface (Fig. 5). Very little accurate information is available on distribution throughout the soil profile but it will vary with nutrient and soil type, and as a rough approximation 50 per cent of nutrients are in the top 10 cm or less.

Nutrients are removed from the soil store by plant growth and by erosion (Fig. 6). Most of those going into plants are recycled to the soil store either by direct physical breakdown to plant litter which is consumed by decomposers, or indirectly through grazing animals and then decomposers, an insignificant amount being exported from the system in animals and animal products. Those removed by erosion are lost from the system. Were it not for the need to minimise the erosional loss, it would not matter by which route the plant nutrients were recycled, that is, all could be recycled via herbivores. As it is, standing plant material is important in reducing erosion and so a certain amount must be withheld from herbivores.

The effect of excessive loss of nutrients by erosion is to reduce plant growth in the next growing period, thus reducing available forage, but more importantly, reducing the protective effect of vegetation and thus possibly causing increased erosion.

EROSION

Erosion is the removal of surface soil and associated litter, organic matter, and nutrients from landscapes. It is a natural landscape-forming process and geomorphically the landscapes of arid Australia can be classified into three broad classes :

1. Erosional - landscapes being formed by erosion e.g. hills and undulating country.

2. Depositional - areas where erosion products are being deposited, e.g. floodplains and fans.

3. Stable - old land surfaces worn flat by previous long periods of erosion or constructional surfaces where deposition is no longer active. A high proportion of arid Australia (e.g. sandplains and dunefields, much of the Mitchell grass and mulga country, the stony tablelands, and Riverine Plain) is in this category.

The sensitivity to accelerated erosion (caused by activities of man) tend to be associated with these categories, both the erosional and depositional landscapes being susceptible. Of the geomorphically stable surfaces the sandy areas would drift if the vegetation were removed but man is not active in these predominantly spinifex-covered areas; a certain amount of erosion occurs on some of the very gently sloping areas if vegetation is destroyed; and plains with heavy clay soils are stable even if vegetation is removed.

Wind and water are the erosive agents. Water erosion is active for only short periods during and following rain but is nevertheless extremely important. Wind erosion can occur at any time except when surface soils are wet, but periods of severe wind erosion are not as frequent as might be expected because they require the coincidence of high temperatures and high winds.

The effects of both wind and water are reduced by vegetation cover according to the relationship shown in Fig. 7 (Marshall, 1972) which shows that low per cent vegetation cover affords greater protection against wind, than water, erosion. This explains why the most severe erosion in Australia is in the medium rainfall parts (e.g. along the tablelands and western slopes of the eastern states) and in the higher rainfall parts of the arid zone (e.g. Ord River catchment and Cobar-Nyngan area of N.S.W.). It also explains why water erosion is a powerful influence, even in really arid areas. Marshall (1970) has developed a formula relating wind erosion hazard to distance between shrubs and their diameter/height ratio. From the relationship the minimum distance between shrubs, of known diameter/height ratios, for effective wind erosion protection, can be calculated.

ENERGY

The main input of energy to the system is from the sun. Most of the solar energy is either re-radiated or used in evaporation and transpiration but a small fraction is converted by photosynthesis into chemical energy in plant material. Of this, almost all is dissipated by respiration of plants, animals, and decomposers and only a small part is exported in animals and animal products. Compared with more intensive forms of agriculture, arid grazing industries are inefficient in converting solar energy to domestic animal products but this is unimportant because solar energy is non-limiting. From a conservation point of view a more important aspect is the higher efficiency of arid grazing systems, compared to intensive agriculture, in the use of fossil energy.

DROUGHT

Droughts are abnormally long periods without effective rain. One effect is that smaller surface waters dry up, which, under natural conditions, must have caused a greatly reduced density of watering points. However, most of the pastoral areas now have a good network of permanent waters and, apart from the fact that the foraging area is reduced to that accessible from these permanent waters, shortage of drinking water is not the main problem.

In general terms, droughts in pastoral areas can be considered as periods of forage shortage which means that their frequency and duration is affected by grazing pressure as well as the climatic conditions which produce plant growth. From a management point of view, conservative stocking during between-drought periods will reduce the duration and severity of periods of forage shortage. The other important point in drought management strategy is early recognition of potential drought conditions and immediate reduction of stock populations to a level which can be supported by the standing forage for the period until the next growth period can be reasonably expected. The longer any excess animals are held, the greater the ultimate reduction will need to be, the poorer the condition of the animals turned off, and the greater the risk of resource damage. This needs to be recognised at grazier, financial, and administrative levels.

LAND USE

About half of the more than 5.7 million sq km of arid Australia has not been used by European man. Most of this is "unoccupied" spinifexsandplains and dunefields but some is similar country included in leasehold land. The other half has been used for a number of purposes which can be classified into two main types - intensive and extensive.

The intensive industries occupy only a few pinpoints in the whole vast area but account for most of the human population and most of the capital investment and returns. They include mining, (e.g. Broken Hill, Mt. Isa, Kalgoorlie, Mt. Newman), irrigation agriculture (e.g. Murrumbidgee Irrigation Area and some areas along the River Murray), and tourism (e.g. Macdonell Range, Ayers Rock, Flinders Ranges). Of these, tourism is more extensive than the others but is restricted mainly to scenically attractive areas which comprise only a small proportion of arid Australia. The tourist industry has many of the features of a watering point in the pastoral industry - the animals concentrate around the watering point with a few strays venturing further than the main body. A potential exists for considerable expansion of the industry but most of this is likely to be in the scenically attractive areas. When it is considered that arid Australia is 25 times the area of the whole of Victoria and the Macdonell and associated Ranges are alone a third the size of Victoria, the tourist potential for the vast expanses of monotonous plains must be rated as very low.

The extensive uses include the grazing industries and National Parks and other reserves. In the last few years there has been a considerable increase in parks and reserves (and there is need for more) but it is not likely that a big proportion of the whole area will be used for this purpose. After all, if 5 per cent of the area is set aside for reserves the remainder would still be 24 times the size of Victoria. The pastoral industry has occupied about half of arid Australia for about 100 years and is the only industry which uses the vast expanses of plains and undulating country. Allowing for unoccupied country and present and future reserves of various kinds, it is likely to remain the only land use on an area at least 10 times that of Victoria.

The ecosystems used for pastoral purposes have been modified by man in many ways. The hydrology has changed, many natural waters have been destroyed, large numbers of man-made watering points have been constructed, changes in vegetation have occurred, some native animals have become extinct, kangaroos have increased, and rabbits and other feral animals have been introduced. They have become man-made ecosystems which can never return to their original state and which will require management by man whatever their future use. If both stock and management are removed they will change but the changes will not necessarily be improvements. The consequences of abandonment by man of any of these man-made ecosystems should be carefully assessed before it is recommended or allowed - even present management practices could be better than no management.

In general little competition for space exists between different land uses. The highly intensive industries use an insignificant area and the existing and potential tourist industry is, and is likely to remain, concentrated on the small proportion of scenically attractive country of little or no pastoral value. Some competition for space exists between reserves and pastoral uses but the area is so large that ample reserves could be established with little effect on the total pastoral area. On an area basis, there is also little scope for multiple land use - some pastoral properties could become dude ranches but even the most optimistic estimates of demand would be satisfied by a very small proportion of properties.

MANAGEMENT POSSIBILITIES

Whatever use man makes of an ecosystem, the costs of management will be related to the value he assigns to it. Characteristically, the broad areas of arid land have a low productivity per unit area and therefore, in practical terms, the cost of management per unit area must also be low. With this constraint, the main aspect that man can control in Australian arid ecosystems is grazing pressure. He can do this in two main ways :

1. By controlling the population of larger animals (domestic stock, kangaroos, and to some extent, rabbits). Populations of smaller animals (particularly invertebrates) cannot be controlled normally.

2. By controlling the distrubution of larger animals by constructing fences and watering points.

Under some circumstances man can also influence the partitioning of rainfall into soil moisture and runoff by constructing furrows or banks. This is generally considered too costly, but, with modern machinery and if spare time labour is used, costs can be as low as 12 to 15 ¢/ha. On areas where a reasonably high success rate and large response can be achieved this cost is not excessive and more consideration should be given to the practicality of mechanical treatment, particularly of degraded landscapes.

These remarks on management apply equally to any extensive use of our arid ecosystems - national parks and reserves as well as pastoral areas.

CONDITION AND TREND

Arid Australia is a vast area with very many ecosystems with different characteristics and different inherent productivities and stabilities. Specific use and management strategies need to be tailored to specific ecosystems and therefore a first requirement for management is an adequate resource inventory.

Another requirement is the development of simple, reasonably objective, methods for assessing condition (status or health) and trend (direction of change in condition) of the various ecosystems, so that management decisions can be based on the health of ecosystems and changes in health . One of the main problems is to find criteria that reflect long term condition as distinct from the short term seasonal fluctuations.

Subjective assessments of present condition vary with the people making them. Graziers and others associated with the industries would say that the lands are in good condition, city people would say that they are very poor. In fact, there is no single answer because different ecosystems have reacted differently. The small areas of landscapes more sensitive to erosion, which were often the more productive ones in their natural condition, are mostly in poor or very poor condition, so bad in fact, that they are unlikely to regenerate merely by removing stock. Most of the large areas of inherently stable ecosystems are in good condition.

Present direction of change in condition is even harder to establish. It is fairly clear that the main deterioration in ecosystem condition occurred in response to high stocking rates, within a decade or two of settlement. Deterioration in condition was not uniform over all ecosystems, the inherently more stable ecosystems degenerated from excellent to good condition, the more sensitive landscapes to poor or very poor condition. Stocking rates fell to a fraction of the peak rates of the early decades but have remained fairly stable since. It seems likely that changes in ecosystem condition have been slight since the early decades of grazing i.e. that the present trend in condition of most ecosystems is essentially stable. In other words it is probable that most of the grazing lands have, after an initial shock, come to a new equilibrium. This is not to say that the new equilibrium is a desirable one - a good case exists on both ecological and productive grounds for improving the condition of some lands, particularly those in poor condition.

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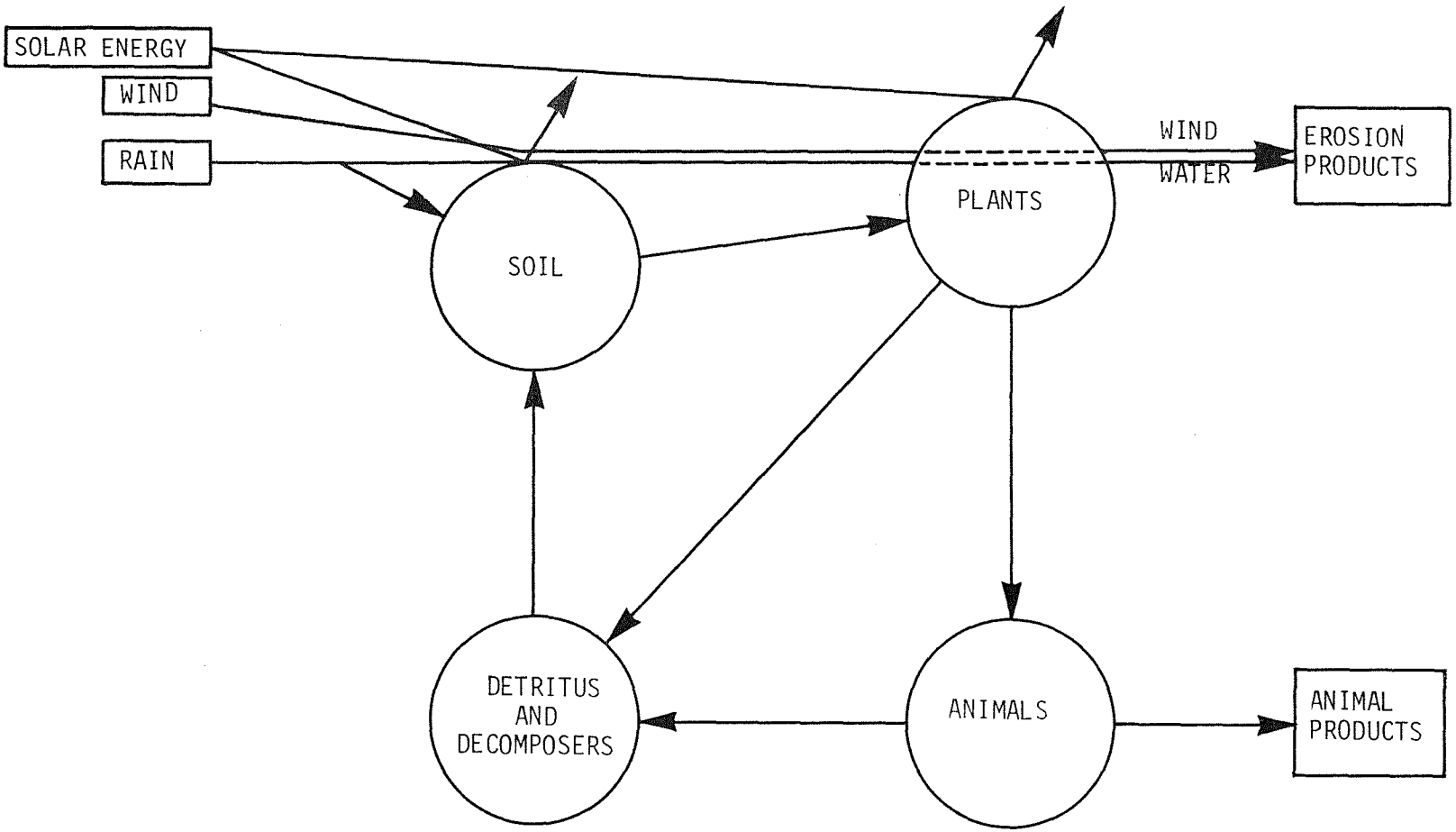

Fig. 1. Simple diagram of an arid ecosystem.

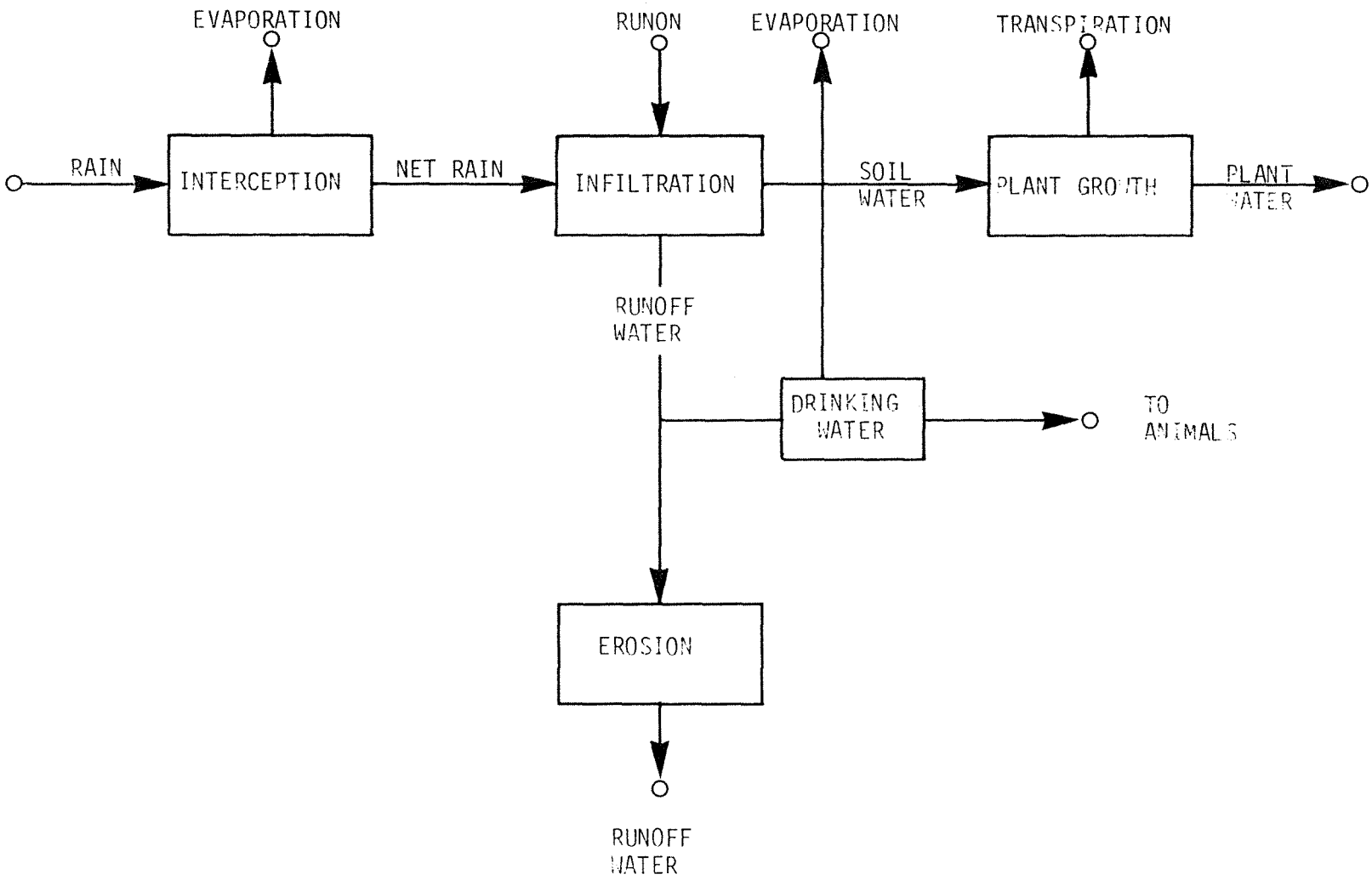

Fig. 2. Water in an arid ecosystem.

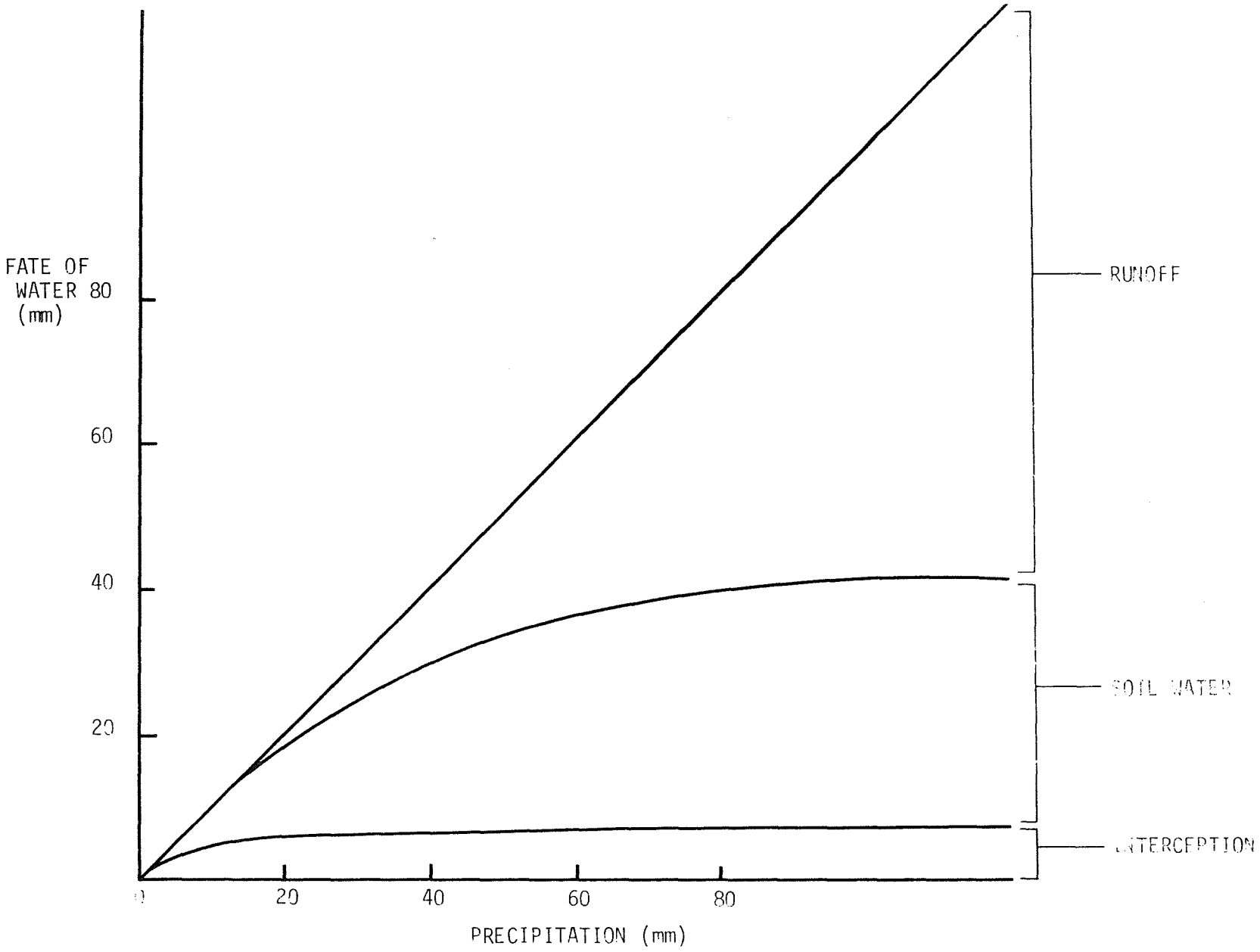

Fig. 3. General form of rainfall partitioning.

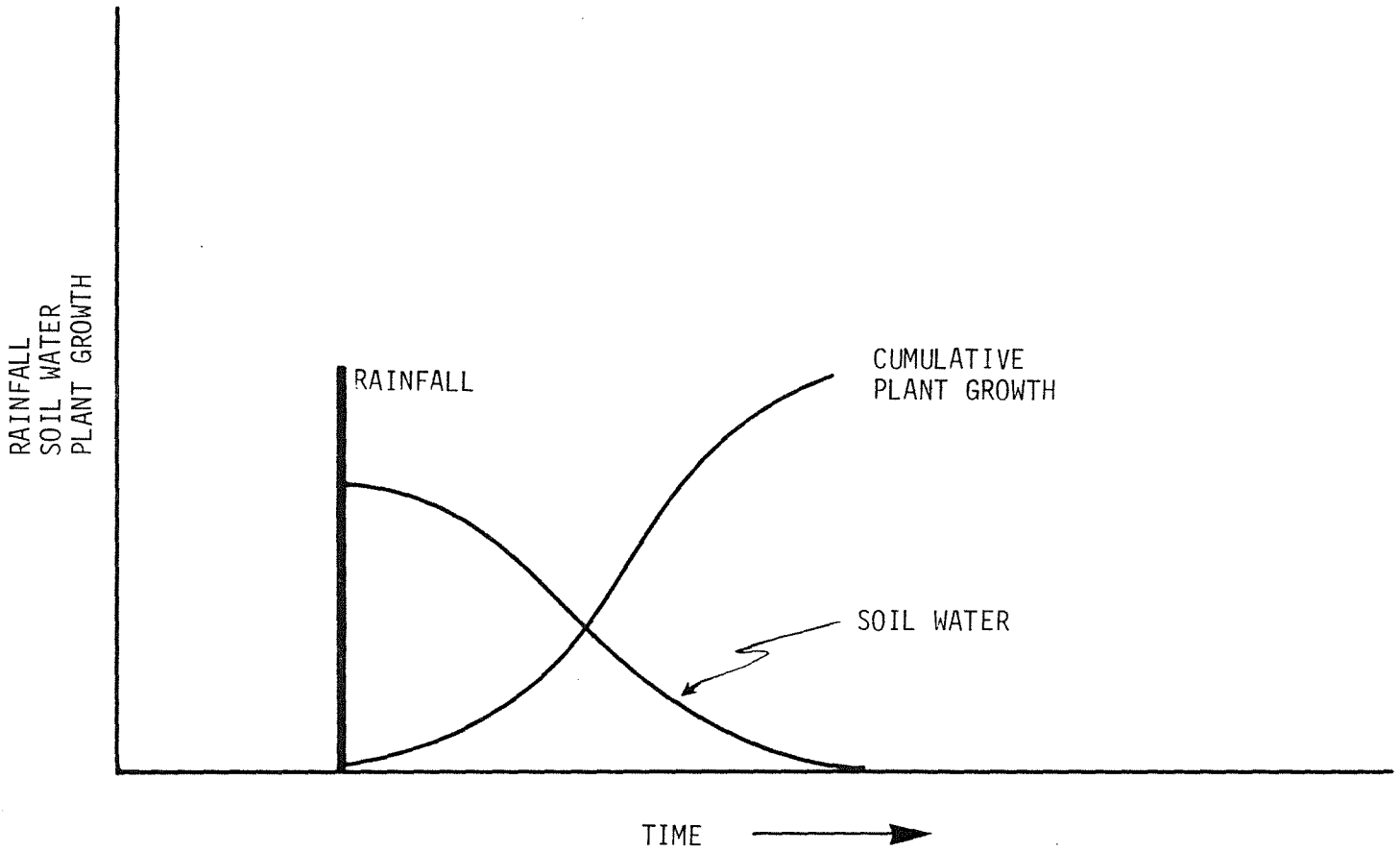

Fig. 4. General form of relationship between rainfall, soil water, and plant growth.

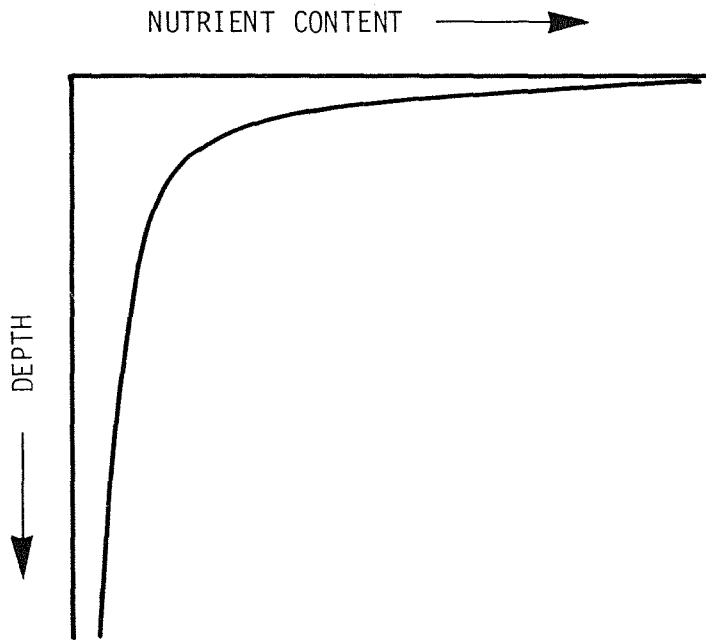

Fig. 5. General relation between soil nutrient content and depth.

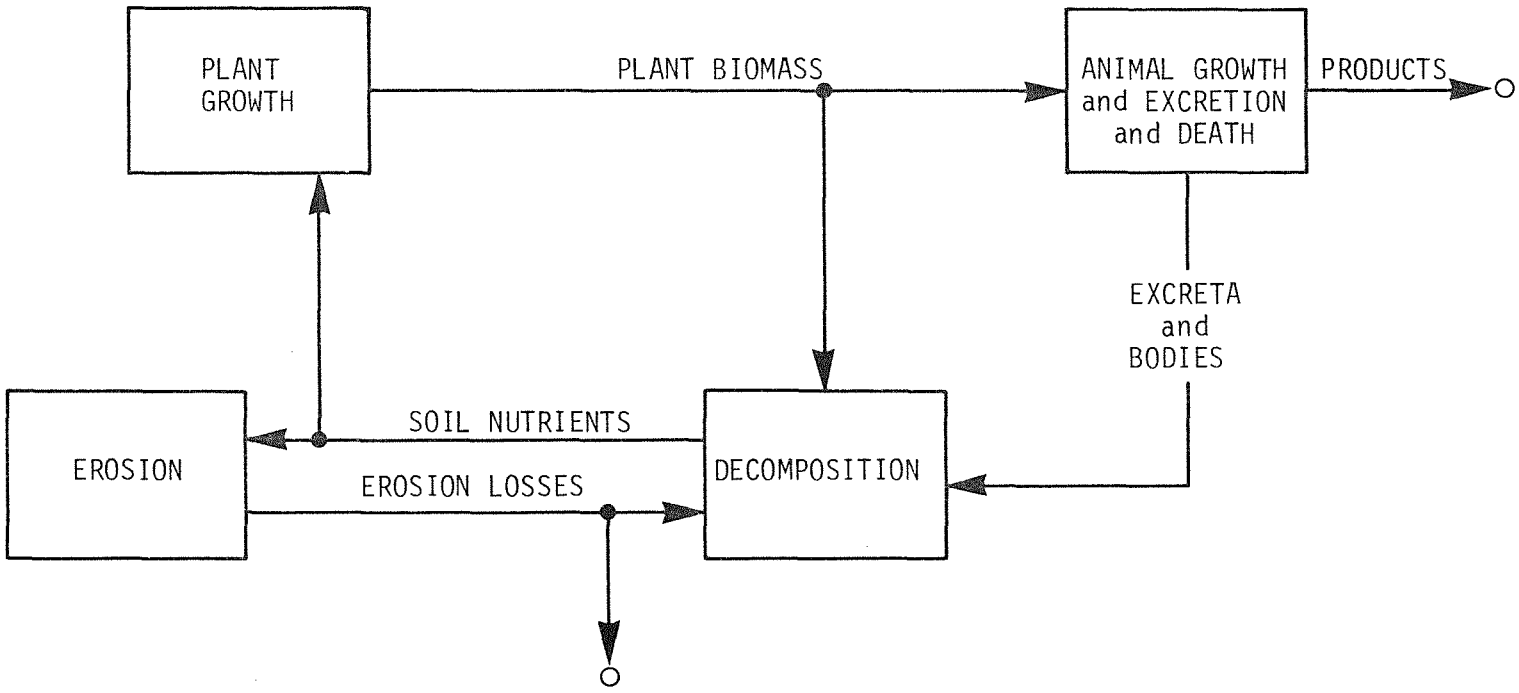

Fig. 6. Nutrients in an arid ecosystem.

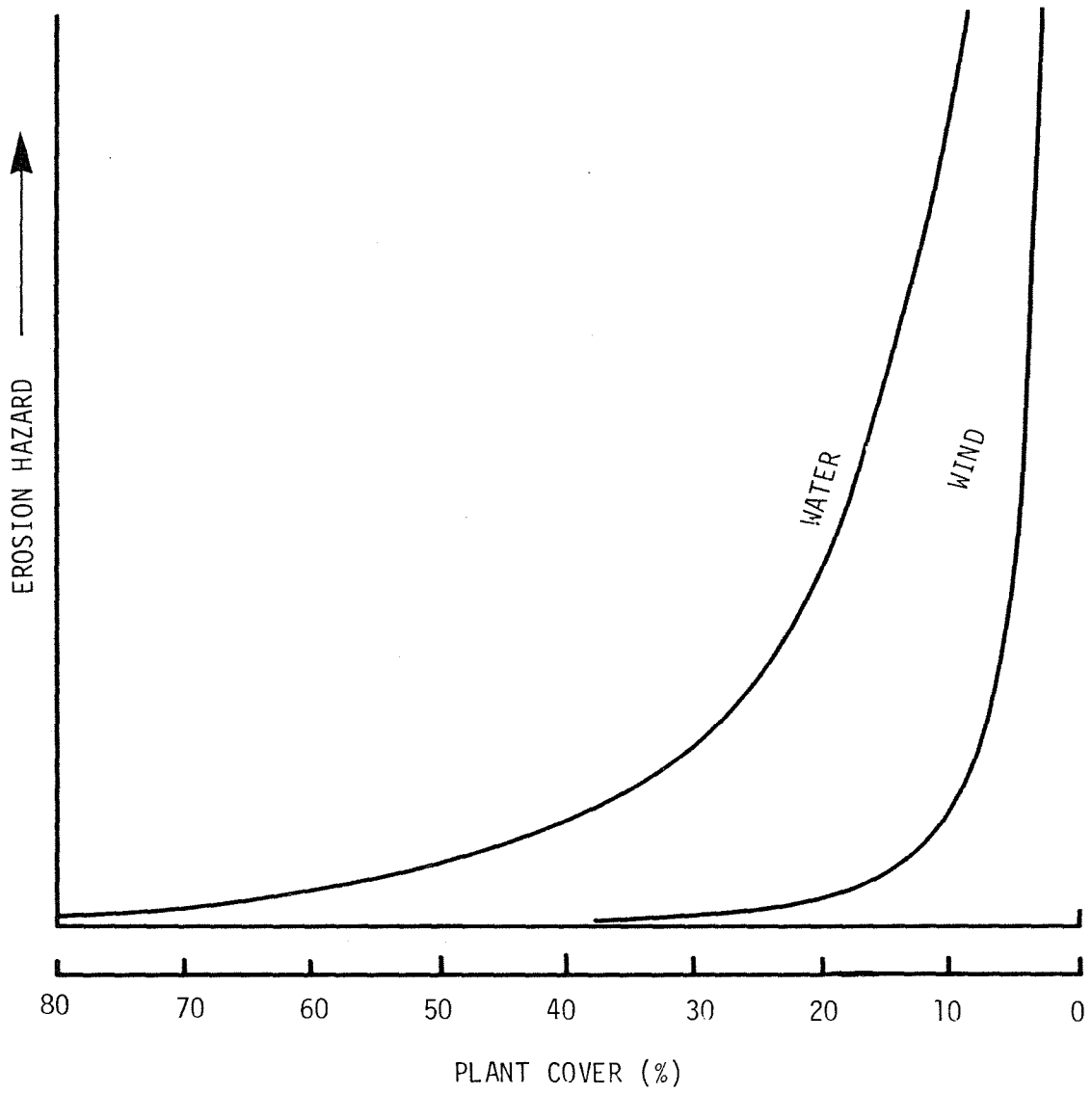

Fig. 7. General relation between plant cover and erosion hazard (after Marshall, 1972).

ARID AUSTRALIA

A NATIONAL PARK

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INTRODUCTION

The Editor of the Journal of the Australian Institute of Agricultural Science was good enough to publish, in the September 1970 number of the Journal, a letter in which I suggested that a substantial part of our arid country might be set aside as a National Park. This was proposed as a conservation measure and it was stressed that it would involve the removal or control of all sheep and cattle carried in the region.

The idea was put forward as a topic for discussion. The comments received have generally favoured the proposal.

The most frequently expressed comment has come from colleagues who feel that it is something of a paradox that a man who has spent so many years in work aimed at increasing production from the land should propose that about one-third of the continent be withdrawn from pastoral use. To me there is no contradiction in this. The last 50 years has seen a marked change in our approach to agriculture - from outright exploitation of our soils and resources to one based on conservation methods of farming. Research and experience during this period have taught us how to farm so that production in the agricultural districts is higher today than at any previous time and the soils are at their highest ever level of fertility.

This has been our contribution to the so-called "green revolution". But it is to be noted that this improvement in the use of our resources has only been possible in areas where rainfall is reasonably adequate for the growth of crops and pastures or where water is available for irrigation. There is no substitute for water. In the more arid regions away from the rivers there has been little or no improvement in methods of land-use despite research which has been actively pursued there for many years. It is my present thesis that if our resources of soils and plant communities cannot be used without destroying them then they should be protected.

Reports on the research in progress in the more arid areas were presented to the Australian Arid Zone Research Conference held at Broken Hill in May, 1970. A perusal of the working papers of this Conference emphasises the need for a new approach to the problem of land-use in the region. Reading these papers triggered my resolve to bring the matter up for discussion.

Sources of Information.

The working papers of the Arid Zone Research Conference provide comprehensive and up-to-date references to our present knowledge of the climate, soils, plant communities, wild-life, pastoral use and other features of arid and semi-arid Australia. The information provided there has been extensively drawn upon in preparing this paper.

An interesting and unusual feature of the research papers is that authors have frequently expressed misgivings concerning the present use of the country for pastoral purposes. May I quote extracts from some of them?

(a) J.P. Ebersohn, Department of Primary Industries, Queensland:-

"In arid areas our task is viewed not so much to increase the biological efficiency of ecosystems but rather to preserve ecosystems in as unspoiled as possible a state so that they may be a continuing recreational and grazing resource".

(b) J.K. Marshall, C.S.I.R.O., Canberra :-

"The stage has been reached when there is a general appreciation of the need for the long-term conservation of the vegetation and soil resources used by the pastoral industry".

(c) D.G. Wilcox, Department of Agriculture, Western Australia:-

"The constitution of the plant communities has been drastically altered as the pressure of use by native animals has been greatly augmented by the introduction of domestic animals whose use of the pasture has been wantonly exploitive".

(d) R.W. Condon, Western Lands Commission, N.S.W. :-

"The arid lands of the Middle East have been devastated by centuries of abuse till they are now largely barren deserts. Many areas of Australia's arid rangelands have also been seriously deteriorated in the relatively short space of 100 years. The fear has been expressed, in responsible circles, that Australia's arid and semi-arid rangelands may suffer the same fate as those of the Middle East if the deterioration continues at the same rate".

(e) R.L. Heathcote, Flinders University, South Australia :-

"It may be found that the emptiness of the arid lands is their most important resource - to be protected and not "developed" by land tenure systems".

The Proposed National Park.

The map of Australia has been taken from Wadham's paper on "The Problem of Arid Australia" published in A History of Land Use in Arid Regions, UNESCO, 1961. The map indicates the approximate boundaries of Prescott's "region of desert formations". As shown, the proposed national park would be located almost entirely within this desert region.

Climate.

The region has very hot summers and mild to warm winters. The average rainfall ranges from 5 to 10 inches, rising to 15 inches in restricted elevated locations. The rainfall is always erratic and unreliable. Evaporation everywhere reaches 100 inches per year and exceeds rainfall for every month in the year. It should be noted that the boundary of the desert region closely parallels J.R. McAlpine's 75 points soil moisture storage maxima isoline. Along this boundary the average amount of soil moisture available in the wettest week of the year is only 75 points. This corresponds with 200 points or more for several months in the year at centres such as Adelaide or Melbourne and indicates the degree of aridity of the region. The line distinguishing summer from winter mean soil moisture maxima coincides more or less with the Tropic of Capricorn.

Perry and Murphy have calculated the length of pasture growing periods and have shown that these are of restricted duration. They are longer in the southern winter rainfall areas than in the north. Of 92 years rainfall recorded at Alice Springs 25 were classified as drought years. It must be remembered that "drought" is a relative term and that a good pasture growing year at Alice Springs would be regarded as a very indifferent season in the farming districts of Australia.

Soil and Plants.

The C.S.I.R.O. Division of Soils map presented in the working papers covers in some detail the area under discussion.

Most of the soils have resulted from varying degrees of modification and stripping of an ancient soil cover derived from deeply weathered laterite profiles. The soils over wide areas are highly leached, acid in reaction and are of low fertility.

Acacia shrublands (mulga) cover about one-third of the zone and occur mainly on hard red soils, sandy loams and rocky outcrops. A further one-third or more is occupied by arid hummock grassland (spinifex). Vast areas of this type are unoccupied and, in addition, the arid woodlands (eucalyptus with spinifex) on lateritic soils and stony hills will not support livestock. The balance of the area, to the south, carried shrub steppe associations (saltbush, blue bush) occupying soils ranging from cracking clays to coarse textured calcareous soils. The lack of water for stock has resulted in much of this type of country remaining unoccupied.

Soil Erosion.

Where this country has been occupied the grazing intensities imposed have led to widespread erosion and to the degradation of the soil and its vegetative cover. There is ample evidence in the spinifex, saltbush and mulga communities that drought combined with over-grazing trampling by stock and cutting of mulga and saltbush have led to the widespread death of the perennial plants. Where this has occurred the process of regeneration is extremely slow and frequently the useful plants have been replaced by weed species.

Grazing has generally been exploitive. The general pattern following settlement has been an initial rapid rise in livestock numbers followed by a spectacular crash. Normally this crash has been precipitated by a drought period and has been followed by recovery to a fairly steady level at about one-third of the peak stocking figures. It must be noted that the management of livestock in these areas is almost always based on the condition of the animals, very rarely on the state of the plants.

J.M. Bowler of the A.N.U. has suggested that more erosion has occurred in Australia's dry country since European settlement than in the previous 15,000 years.

Economic Considerations.

It is important to note that only some 60% of Australia's arid/semi-arid country is occupied by pastoral and mining interests. It is particularly significant that the largest proportion of our vacant lands are found in the arid areas. Even at the present time no economic use has been found for this country.

The major part of the occupied rangelands is held under some form of Crown lease tenure. There is only very limited freehold land. E.J. Waring of the Bureau of Agricultural Economics has pointed out that, from the costing point of view, land in the arid zone is of zero value. An overwhelming part of the price paid for properties is for livestock, structural improvements, plants and machinery. Cattle may make up to 80 per cent of the total value of a property, sheep up to 46 per cent.

The rangelands covering approximately 75 per cent of Australia provided grazing for some 24 per cent of the sheep and 30 per cent of the total beef cattle in 1967. The sheep were almost exclusively merinos for wool production, the cattle were predominantly shorthorn. From 1957 to 1967 sheep numbers in the region decreased by 18 per cent, beef cattle by 16 per cent. These figures compare with increases of 22 per cent and 35 per cent for sheep and cattle respectively in the rest of Australia during the same period. Figures are not available for the arid 30 per cent of Australia but this zone probably carried considerably less than 5 per cent of the livestock. The number of pastoral properties is not known but is probably of the order of 100 to 200.

The Future.

The decision that must be made is whether we should continue to exploit the grazing provided by our arid areas with the very likely consequence of producing another feature-less desert or should we, with Heathcote, recognise that "the emptiness of the arid lands may be their most important resource". The pastoral industry in general is not in a viable state in the region at the present time and production will continue to decline as the condition of the plant associations deteriorates. If it is decided to discontinue grazing the problem becomes one of administration - how best to manage the area as a permanent park or reserve with the emphasis on the tourist industry, already a major activity in the region, and on mining. The idea of conserving the arid areas is not a new one. Large areas have been set aside as reserves and some 15 other areas within the proposed national park have already been proclaimed national parks. An interesting example of the type of action that can be taken was the establishment of the Simpson Desert national park by a tri-partite arrangement between South Australia, Queensland and the Commonwealth.

H.H. Finlayson in the thirties proposed that substantial areas west and south west of Alice Springs should be preserved as national parks. His studies and report (The Red Centre) were concerned essentially with the wild-life of the region. The present situation regarding non-domesticated animals there is reviewed by D. H. Wood in the working papers of The Arid Zone Research Conference. In recent years N.B. Tindale has proposed the establishment of an extensive national park embracing parts of South Australia, Western Australia and the Northern Territory.

Administration.

The present proposal is that the arid area with boundaries from Shark Bay (Hamelin Pool) to Kalgoorlie and to Broken Hill, north to Mt. Isa and west from Mt. Isa to the coast should be declared a national park. At present this region is administered from Canberra,

Perth, Adelaide, Sydney or Brisbane, centres remote from the people and problems of the region. The suggestion is that control should be vested in one authority only and that this authority should be located in the area at Alice Springs.

If the status of the area is to become that of a national park it would possibly be wise to exclude the cities of Kalgoorlie, Broken Hill and Mt. Isa. If on the other hand, it should be decided that the area could be better managed as a State in its own right, with tourism and mining as the main industries, then these urban centres might well be included.

The change in status of the region would involve the cancellation of the existing pastoral leases. To avoid hardship the lessees should then be compensated financially for existing fixed improvements. So much of the capital invested is in livestock and disposable plant and equipment that the cost involved would not be great. A number of the lessees, located at strategic points, might well be invited to continue to occupy their homesteads and to accept employment as national park rangers or wardens. Others again might be encouraged to develop motel-type accommodation for tourist use. The homesteads are located on the only permanent waters and are generally in the most attractive situations within this Never-Never land.

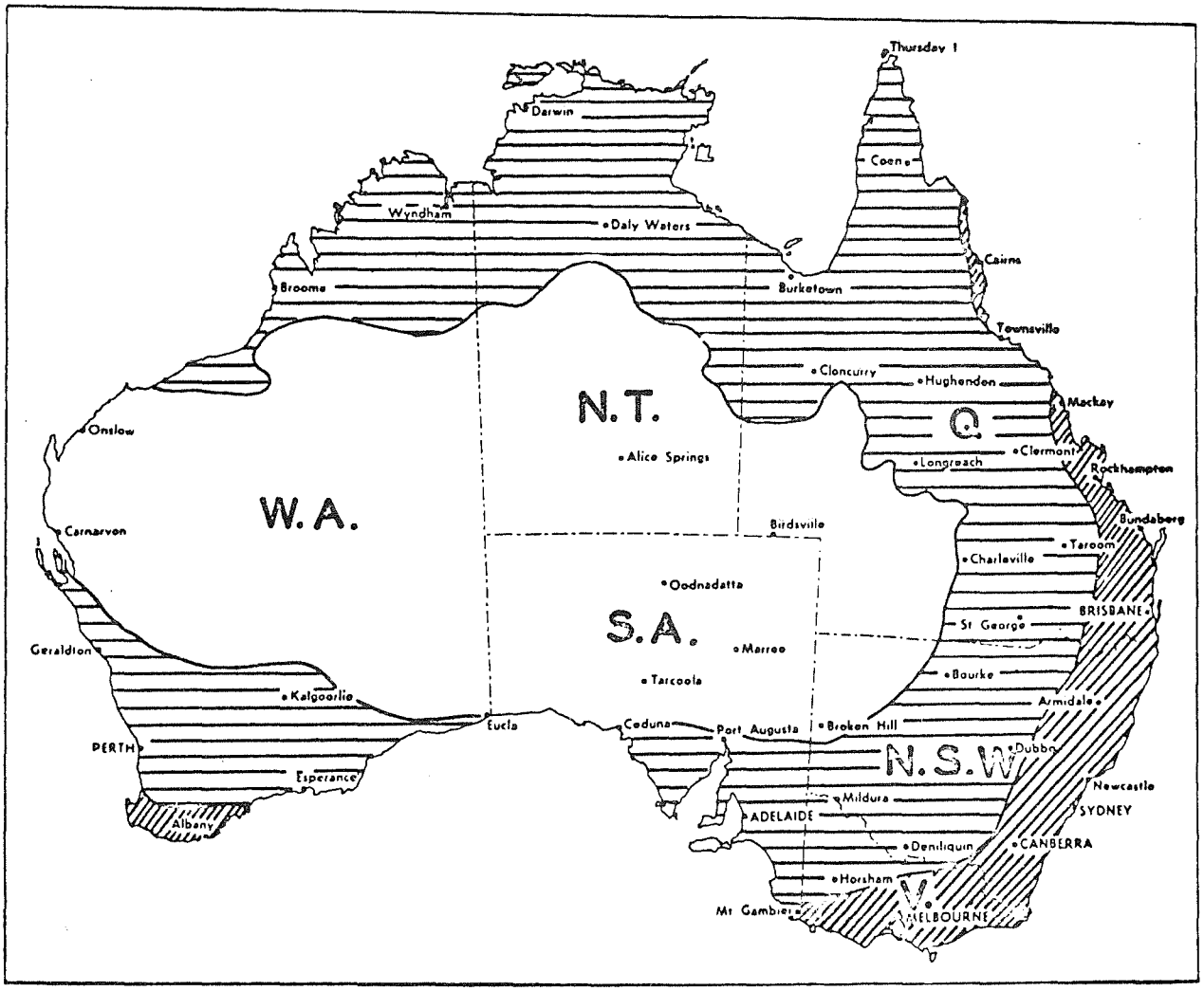

FIG. 1. Showing the boundaries of the States, the approximate boundaries of 'the region of desert formations' (Prescott) and the zone of the subhumid areas (not more than 3 months of aridity annually).

PERCEPTION OF ARID AUSTRALIA

SOME GEOGRAPHICAL CONSIDERATIONS

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Contents

INTRODUCTION.

The basic hypothesis of this paper is that our perception of arid Australia (i.e. our knowledge of, and attitudes ot it) has changed from the time of the first European ccntacts with the arid western coasts in the seventeenth century to the contemporary views of the inland. It is further suggested that this change over time has resulted from increased recognition of the nature of the arid land resources, from the lessons of experience in attempting to use these resources in arid land settlement, and from the influence of external philosophies and attitudes to the resources of the environment in general.

Time does not permit the full documentation of this hypothesis but the main arguments will be presented in three parts. First, the changing attitudes to and knowledge of the arid lands will be examined. Secondly, the aims and achievements of arid land settlement will be outlined. Finally, suggestions will be made, drawing upon United States experience, for a review of our contemporary perception of the arid lands, as a necessary pre-requisite to our future policies of arid land use.

ARID AUSTRALIA - THE PROBLEM OF DEFINITION

Arid Australia has been and still is, defined in many different ways and the differences need explanation. The problem of how to define arid Australia has taken two major forms. First, knowledge of the arid lands has evolved through time and as a result the definitions (reflecting the available knowledge) have changed through time also. Second is the fact that the arid lands can be defined differently according to the aim of the definition. Thus the wheat farmer, the pastoralist, the mining engineer, or tourist have different expectations and tolerances of aridity and each would have different definitions of an "arid zone". Within this symposium we are obviously attempting to come to a consensus of definitions, to make sure that we are at least talking about the same thing. But it is not as easy as might at first appear.

The Acquisition of Knowledge of Arid Australia.

Most of the earlier knowledge of arid Australia was gained by the first-hand experience of explorers, but speculation on the facts always outran the explorers' tracks. One of the major tools of speculation was reasoning from analogy with other known places. Between the tentative and unimpressive seventeenth century accounts of the western coasts by Dutch and British navigators, and the first permanent settlements in humid New South Wales, Jean Pierre Purry, a Swiss employee of the Dutch East India Company used analogy to forecast the condition of part of the arid lands in 1718. Having made a study of the world climatic belts most suitable for European settlement, he suggested that the optimum zone for agriculture and mineral development was between the thirtieth and thirty-sixth parallels of latitude, especially about the thirty-third parrallel, which in the case of Australia was Nuyts Land at the head of the Australian Bight (Perry, 1966, p.141).

Even once permanent settlement had begun, the myths of the interior continued long after exploration had begun to suggest the facts as we know them. One of the first local-born writers, W.C. Wentworth, used analogy to forecast a Mississippi-like river system crossing the interior from southeast to northwest in 1819. A year later, when the reports of the explorers (who had traced the headwaters of this system until bogged down in swamps) became available, he merely changed the analogy to that of the Great Lakes, from which an Australian St. Lawrence river would flow to the northwest coast (Heathcote, 1965, 20-21). In 1830 Maslen drew such a system on to his map of inland Australia and began a long sequence of cartographic speculation which was only effectively subdued by the discovery of the Lake Eyre drainage system in the 1860s and 1870s. (Maslen, 1830, map frontispiece).

Analogies on the natural features were parallelled by analogies on the potentials for settlement, mirroring Farry's earlier estimates. Thus, Captain Vetch in 1838 calculated the future population of the continent by dividing it into nine convenient units and awarding each the population (19 millions) of the European nation nearest in size, assuming of course an analogous land productivity potential (Vetch, 1838). Speculations on these lines was never daunted by facts as we shall see later.

The explorers entering in the arid lands faced environmental challenges which were to mould their appraisal of its resources and often distort the picture they brought back to the settled lands. In fact all exploration of arid Australia has faced environmental conditions which deteriorated the further one went, since all explorers entered from the humid rain of the continent and headed, initially at least, for the arid core. Not only did conditions such as forage and water supplies deteriorate inland, but they varied considerably from season to season so that bare sun-baked mirage-crowned clay plain in one account became a well-watered sea of grass in the next. Even access into the interior from the settled humid lands was not always easy. The parallel dune systems of the Simpson Desert were, and still are, a formidable barrier to the east and the salt-crusted clay pans of the Torrens, Eyre and Frome lakes were significant barriers to the south. Indeed, not until the use of aircraft in the 1930s were the basic patterns of the sand dune systems established, and Sir Grenfell Price commented on the European "invasion" of the Lake Eyre basin that :

> the invaders discovered Lake Eyre with horses in 1840; they examined its northern shores with camels in 1874-5, but it was not until 1951 that they solved (by the use of motor trucks, motor boats, and aircraft) the extent of its filling and evaporation (Grenfell Price, 1957, 188).

To the problems of the environment were added problems of communicating the knowledge so painfully gained. All the official explorers saw their reports in print in the Government Gazettes and newspapers, and occasionally in their own books. Many of the private explorers, however, who were more numerous than the official parties, kept their knowledge to themselves and only showed it by their applications for pastoral runs at the state lands department or much later displayed it in their published memoirs or private diaries which were lodged in the official archives (Dowling 1859, Gow 1860).

The literary descriptions themselves needed care in their interpretation, for the words used did not always mean what the reader could be expected to think that they meant. Terms such as "river" and "stream" gave a false sense of permanence to what were usually seasonally dry watercourses, while other names such as "creeks" had their meaning changed to suit new circumstances (Turner, 1966).

Aboriginal names were occasionally adopted for peculiar natural features, especially water bodies (eg. billabong, tallywalka and warrambool) but generally speaking the literary sources relied on a terminology which made few concessions to an environment for which it was not designed, and as a result has left a legacy, still to be seen on the maps of the arid interior, of misleading and often inaccurate connotations.

In sum, knowledge of the interior was initially based mainly on analogy, supposition and myth and subsequently was gained only through hard first-hand experience, which occasionally degenerated into what the American Geographical Society rather unkindly called in 1876 "little more than a race for life across the sands". The experiences themselves were often contradictory and even explorers of the calibre of Sturt and Mitchell disagreed over what they had seen (Mitchell 1838, p. 209). By 1871, however, when the German geographer Petermann published his widely acclaimed map of Australia (in 8 sheets at 1:3,500,000 scale) summarising the accumulated knowledge, the basic drainage patterns of the arid lands were outlined and the main sources of surface water already plotted (Petermann 1871).

Yet, as we have seen for Lake Eyre, the detailed knowledge was acquired over a longer time period. Thus, it was not until the 1950s, when the publication of the 1:250,000 map sheets was completed, that complete topographic cover of the arid zone at a large scale was achieved. Even now, the equivalent scale geological maps do not cover the whole of the arid zone (Fisher, 1969, p. 59).

Apart from the basic land exploration knowledge of the arid zone has been built up from three other major sources. The first in time were the specific official enquiries into particular problems of settlement in the arid lands. A list of the main relevant enquiries for each state and territory is in preparation and although incomplete it is already evident that the major items of enquiry have been problems of the pastoral and agricultural land use (see also Borchardt, 1958). Most of these enquiries, particularly in their Minutes of Evidence, are invaluable records of changing knowledge of, and attitudes to, the arid zone opinions of both officialdom and the local men on the land.

A second source, of importance since 1945, has been the reports of the CSIRO Land Research and Regional Survey teams which have provided basic terrain, drainage and vegetation classifications for approximately 1/5 of the arid zone. It is unfortunate, however, that this source will no longer be available, as no further reports of this type are to be produced.

Finally, a third even more recent source has been the periodic conferences specifically called to deal with arid zone problems. Three have been called by the CSIRO (CSIRO 1960, 1965 and 1970) and one by the Australian Academy of Science (Slatyer and Perry 1969). These, convened to provide an overview of the arid lands, have so far tended to concern themselves mainly with the "traditional" questions of arid land use, namely the problems facing pastoral and agricultural land use. It is perhaps indicative of the state of our knowledge that studies of the architectural and social problems of life in the arid zone have only recently come under review (Saini 1970).

Defining the Arid Zone.

With increasing knowledge from exploration and the collection of climatic data increasingly refined attempts were made to define the extent of the arid inland. The scientists faced the same semantic problems as the explorers for many of their definitions used the term "desert". This brought them into the realm of politics, for as Ann Marshall commented, in her 1948 study of their attempts:

> A desert in Australian politics is something hot and plantless that exists somewhere in the world but not in Australia (Marshall, 1948, p. 168).

The word desert, particularly in the first half of the twentieth century, had moral and emotional connotations for a newly unified continent. The implications of these connotations, however, can be only hinted at here and will be best illustrated when we examine the policies of arid land settlement. First, we need to establish the facts as the scientists saw them.

Briefly, the definitions of the arid zone have two forms, the first being a complex of climatological and ecological criteria attempting to exclude human activities, and the second a complex of ecological and economic criteria in which human use of resources forms part of the definition. In effect, these provide a contrast between a basically climatological and a basically geographical definition.

The climatological definitions prior to 1948 are well summarised in Marshall 1948 and examples of the resultant boundaries of the arid zone are illustrated in Fig. 1. Basically, from Koppen's definition in 1923 to the definition adopted by the UNESCO World Arid Zone Research Programme in 1953 (Meigs 1953), the scientists were attempting to provide a formula which could use the available climatic data (i.e. rainfalls and temperatures) and provide a reasonable correlation between arid limits as observable in the field (through natural vegetation changes) and those limits as mapped from application of the formula. These were attempts to define a special ecosystem without reference directly to any human needs or activities.

It was but a short step from this type of definition to one which did take note of man's needs and define aridity in terms of the specific moisture requirements of his domesticated plants. One of the first attempts to define the boundaries on such terms appeared in 1949 (Prescott and Thomas 1949) and the most recent version isshown on Fig. 2A.

Other scientists saw the need in the definition to allow for man's experience of the conditions facing him. Thus, in 1940, Griffith Taylor, one of the founders of Australian geography, suggested :-

> A desert is a region of small rainfall (sometimes, however, amounting to 15 inches in hot regions) with a sparse and specialised plant and animal life. It is not found capable of utilisation by stationary pastoralists, even after the borders have been occupied by this class for fifty years (Taylor, 1947, p. 103).

Significantly, this idea is implicit in the recent definition of the Australian "rangelands" which is reproduced below :-

> The rangelands are those parts of Australia where rainfall, on a given piece of land, is too low or unreliable for cropping or extensive sown pastures to be economic .....in the south and east the boundary is the low rainfall margin of wheat growing. In the north it represents the low rainfall margin of potential Townsville Stylo growing and has been determined from agro-climatological analyses (CSIRO, 1968-69).

Virtually the same definition was used for the 1969 Australian Academy of Science Conference on Arid Australia, published as Slatyer and Perry 1969. For the contributors the zone was defined as :

> those areas on which rainfall on a given piece of land is inadequate for regular cropping or for extensive sown pastures to be economic. This means, in effect, those areas in which rural enterprises are limited to pastoral industries dependent on natural pastures. These boundaries approximate the 10 inch isohyet in southern WA, SA and south-western NSW, the 15 inch isohyet in eastern NSW: the 20 inch isohyet in southern Queensland; the 25 inch isohyet in north-eastern Queensland; the 30 inch isohyet in north-western Queensland; NT and northern WA (Letter from the convenor, R.O. Slatyer, 27 June 1968).

The boundaries are virtually the same and only the latter has been reproduced on Fig. 2B.

For convenience, this latter boundary (Fig. 2B) has been adopted for this paper, but it should be noted that both maps of Fig. 2 show two types of arid lands and some explanation is necessary. In Fig. 2A the core arid zone is that area where there appears to be an absolute limit to moisture available for any plant growth. Plants growing in such areas (apart from in locally superior microclimatic conditions) are "accidents" of weather rather than climate. The difference between this and the outer limit of the arid lands is of degree of tolerance of the specific moisture needs of man's domesticated crops such as wheat, barley and the sown tropical grasses such as Townsville Stylo. In this area such crops may grow for a short time but yields are very uncertain. Thus, the core area of less than one month growing season represents an absolute limit, while the peripheral zone of one to five months growing season represents an area of high risk of crop failure. In Fig. 2B this is mirrored in the division between the unoccupied and the pastoral lands, although there is local distortion as a result of the moister conditions around the Macdonnell Ranges in the centre and the accessibility along the north-south rail and road routes. The outer boundary of the arid lands therefore appears to include a core where no biotic resources have yet been recognised and a fringe where some biotic resources have been recognised and are currently being used. It must be remembered, however, that such boundaries are based only on current knowledge and refer only to the biotic resources.

LAND SETTLEMENT IN ARID AUSTRALIA.

Aims

Official policies on land settlement in Australia were initially drawn up in Britain, and not until mid-nineteenth century and the granting of representative state government were the basic policy decisions made locally. Even then, policies were designed for the peripheral humid lands of relatively high unit-area productivity and with the emphasis upon small family owned and operated itensive farms. In this, local policies were not unique as the latter half of the nineteenth century saw parallel settlement policies being evolved for the interior plains of North America. Indeed it was recognised at the time that the parallel policies - of establishing a yeoman farmer population upon the "empty" lands - faced similar problems and there is abundant evidence in parliamentary papers of all states, of reports from other areas of the world on legislation, irrigation methods, types of crops and livestock, and methods of land survey (Powell 1971, Rutherford 1964).

The general policies noted above, foreshadowed the complete occupation of the continent, including the arid lands, by first a pastoral and then an agricultural form of land use. The large pastoral properties which began to impinge on the semi-arid fringes of the arid lands in the 1870s and 1880s were seen as but the advancing pioneers of civilisation, a civilisation founded on agricultural small holdings. To explain this and our subsequent policies towards settlement in the arid lands we need to see the historical and geographical contexts and to sift out the contemporary philosophies towards the environment.

Nineteenth and even twentieth century land policies in North America as well as Australia have beendominated by rationalist thinking which sees the deserts as "waste" lands to be "developed" - a challenge of nature to be mastered by the ever resourceful rational, thinking man. All things were seen as possessing a material value to man, apparent or inherent: waste lands could be used, the "deserts" reclaimed. All that was needed was art (in the sense of skill) labour and capital (Yi Fu Tuan 1966).

Optimism went hand in hand with rationalism; if there were problems in nature, man could rectify them, even to improving the climate. A series of above average annual rainfalls supported the "rain follows the plough", hypothesis in the 1870s in the southern fringes of arid Australia: afforestation was claimed to modify the climate in the 1870s (and is still highly regarded by some, see St. Barbe Baker, 1966); there were hopes of further modifying the arid climate by flooding Lake Eyre with sea water by a canal from Port Augusta in the 1880s (Commonwealth, 1937, Appendix pp.924-5), and dry farming pushed the wheat lands into the arid zone in the early years of the twentieth century (Gordon, 1906). Even the NSW Government Botanist caught the enthusiasm and commented in the Federal Handbook prepared for the meeting of the British Association for the Advancement of Science in Australia in 1914 that :

> It is interesting to note how year by year the 'wheat line' in all the mainland States has been pushed into the 'desert' and man is getting remunerative crops from regions of low rainfall and light sandy soil which would have been looked upon as chimerical a decade ago. In other words, the 'desert' land is shrinking year by year. (Maiden, 1914, 173-4).

To optimism we must add patriotism. Griffith Taylor had his 1911 school text on Australia banned from use in Western Australia for several years because it dared to talk of deserts in that state (Taylor, 1958, p. 138-9). Despite the evidence which had accumulated by that date of the nature of the interior, many were unwilling to admit that there were any faults in this wide brown land. The Commonwealth Meteorologist, three years later at the British Association meeting, mentioned previously, claimed that "the preconceived notion that Australia is the particularly drought-stricken and precarious area of the earth's surface" had been emphatically contradicted by the climate of the preceding decade (which had followed, we might add, the disastrous droughts of 1895-1902!). He admitted that seasonally dry periods were liable to be experienced, but were not to "be regarded as drought, and an evil, but rather as Nature's wise provision for resting the soil" (British Association, 1915, p.442). Even droughts could be rationalised (Heathcote, 1969a).

Throughout the 1920s and occasionally subsequently the rival claims of the optimists and pessimists for the future of the interior arid lands, have illustrated the extent to which nationalism had been translated into a feeling that the nation ought to develop the inland as a moral obligation (Perry 1966 and Taylor, 1958, pp. 178-181). Such ideas seemed to focus on the Northern Territory in which the Commonwealth as landlord faced the responsibilities of developing both the "tropical north" and the "desert" in one unit (after the unsuccessful attempt to split the problem politically by the creation of 'Central Australia' in 1927-31). Yet the extent of the problems were only reluctantly admitted, and past successes in humid land settlement were assumed to be automatically transferrable to the arid lands, as a Territory enquiry noted in 1937:

> The wilderness has so often been successfully subdued, natural difficulties have so frequently been overcome, that many Australians still continue to hug the delusion that great prospects comparable to those of the populous parts of the continent lie hidden in the (Northern) Territory. Indeed, this view found expression in a pamphlet issued by the Prime Minister's Department as recently as the year 1933 (Commonwealth, 1937, p. 830).

When dry farming did not seem to be the complete answer in the 1930s, renewed hopes for imigration were raised by Bradfield's Scheme to water the inland with the surplus tropical rainfalls from Queensland via the Channel Country (Bradfield, 1941). The controversy, however, has continued. The "dead heart" (Gregory 1906) became the "dying heart" (Pick and Alldis, 1942) where the "battle for the inland" (Timbury 1944) - the man : nature struggle - was to replace the contemporary man : man struggles of the Second World War. Recently, however, the economists have begun to question the costs, suggesting that "art", capital, and labour" could be better employed in traditional land uses in less arid environments (Davidson 1965 and 1969).

To the rallying cries of rational materialism, and nationalism, the scientists have added their philosophy of conservation. Perhaps significantly, the scientists achieved their greatest initial successes in the arid zone with the original inhabitants. As a result of pressure building up among anthropologists from the 1920s awards, an increasing proportion of land in the arid zone has been set aside as reserves for Aborigines. These reserves predate the scenic and flora and fauna reserves of the last decade, and were conceived of as retreats and refuges for what were thought to be the dying remnants of the first arid zone inhabitants. Success in setting aside large areas to preserve the arid landscapes against development or to control that development have only appeared in the last decade but the pace of reservation of land is increasing (Costin and Mosley, 1969).

Achievements.

In general the first impression is that the original aims of land settlement in arid Australia have not been achieved. Approximately 27% of the arid zone is still unused or "waste", and of the remaining 73%, the bulk of the area is extensively occupied for grazing livestock (Fig. 2B) and by a sparse, still largely male, population isolated in remote pastoral homesteads. To these we must add the occasional isolated urban community grouped either around remote mining projects, or equally remote tourist attractions. In 1966, a total population of some 336,800 (2.8% of the national total) occupied 74% of the continent; not an impressive record for 178 years of settlement the developers would say.

The impact of settlement policies is even less impressive when we look at the picture of land tenure. If we divide the existing tenures according to their content, duration, size, permitted uses and possible ownership (Heathcote 1969b), we can distinguish three major types. First, is alienated land, where virtually no restraints upon ownership or use exist; second is leased land, where a specific item or resource is owned under limitations on use or duration of ownership; and third is reserved land, where individual ownership is excluded and strict controls on access and use apply. In general, the aim of land settlement in Australia was to transfer all land from the Crown, who had claimed it from the Aborigines, to private ownership i.e. alienation, excluding only land required for public use as reserves eg. roads and land for public institutions. In effect this has not been achieved as the pattern of current tenures (Figs. 3 and 4 and Table 1) shows.

It is immediately apparent from these figures that, despite the original intentions, alienated land is not a feature of the arid zone. The areas of this type are either "tide marks" left as relics of unsuccessful attempts to intensify land use by introducing

agriculture (see South Australia area, Fig. 4., described in Meinig 1962), or contemporary attempts to repeat the process (see Esperance area of Western Australia), or relics of land purchased around pastoral station homesteads or improvements to "protect" them for the leaseholders against speculative settlement by potential blackmailers (Heathcote, 1965). Over half the arid lands are in leases or licences for pastoral purposes, and only about 17% of the arid zone has the size of these leaseholds tied to family "living areas". Elsewhere, often across state borders (eg. from NSW to SA, Fig. 4), the conditions become much less restrictive (Table 2). A small, but increasing proportion of the arid lands is in some form of reserves, mainly for Aborigines, but also for national parks, sanctuaries, travelling stock, and military purposes. Legally vacant land remaining beyond the above is still a large proportion of the arid zone, significantly coinciding with the major areas of linear sand ridge terrain of the Great Victoria, Great Sandy and Simpson deserts.

The surface tenures are only part of the picture, however, and Fig. 5 shows some of the extent of the mineral leases, which with the reserves are the fastest growing type of land tenure in the arid zone. Approximately 34% of the zone is in petroleum leases alone.

The failure of the policies of land alienation has left the Crown as the main arid land owner, either directly as in the vacant and much of the reserved lands, or indirectly (ultimately) for the leased lands. Thus if any modifications to tenures are envisaged in the future, the potential disruptions to, and cost of modifying, existing tenures is that much reduced.

In fact, the resources of the arid lands have over the years been differentiated in the processes of land settlement, and ownership has been granted to separate items rather than to the whole. The result is summarised in Fig. 5 where the array, or "strata", of resources at any one location has been disposed of to different owners either commercially (mainly by lease), or non-commercially by different types of public reserves. This process has not been unique to the arid lands, but seems to have been most widespread and successful here. Indeed, if any feature of the introduced (British) tenure system can be said to have been successful in the arid lands, it would seem to have been the lease concept - particularly as adapted to pastoral, and more recently, mining land uses. Under this system, use for specific periods of time, of specific resources, and at specific intensities, can be regulated by the Crown by terms built into the lease agreement.

THE FUTURE OF ARID AUSTRALIA - THE ENIGMA

Before summarising the challenge of arid Australia as seen by a geographer, it is worthwhile briefly commenting upon the parallel American experience, particularly as an important report on the American arid zone has just appeared.

The American Experience.

The American efforts to develop their arid zone (some 11% of USA) parallelled in concepts and time the Australian experience, and with relatively comparable results. Thus the bulk of their arid zone (some 90%) is still in Federal or State ownership, not private lands as originally intended; the population (some 4% of total) is sparse, although in USA manufacturing industry absorbs a much larger proportion of the workforce; up to most of the national parks and reserves for indigenous population are to be found here on in adjacent semi-arid lands (68% and 62% of the national totals respectively for arid and semi-arid zones; 33% and 30% respectively for arid zone alone); and here, as in Australia's arid zone, are to be found some of the areas of environmental decay through man's mis-use of the resource bases in the past.

The Americans had the advantage of a very early and comprehensive report on the potentials of the arid zone (Powell, 1878) but rejected it as not coinciding with the laissez faire yeoman farmer concepts of the time. Almost a hundred years and several comprehensive reports later, they do appear to have accepted the concepts implied in a major report published in 1970 (United States, 1970). The main proposals of this report are worth precising here, as of some relevance to our arid lands. The Report stems from an enquiry into the state of the US Federal Lands and enquired into their optimum future use for the maximum benefit of the general public.

The Preface to the Report notes that :

1. National pride in public land seems to be replacing the desire for private ownership.

2. "There are both known and unknown values in these (Federal i.e. mainly arid) lands".

3. The planning proposals are not projected beyond the year 2000.

4. The scope for resource use planning was deliberately kept very wide - "in addition to the traditional resources of minerals, timber, forage, intensive agriculture, water and fish and wildlife, there were included outdoor recreation and the various spatial uses such as for residential, commercial. and industrial purposes".

Among the recommendations of the Report the following appear to have relevance to Australian conditions:

1. The public lands should in future only be disposed of where the general public will obtain maximum benefit from non-public ownership, ie. "While there may be some modest disposals, we conclude that at this time most public lands would not serve the maximum public interest in private ownership".

2. All public lands should be examined and their future use designated to give "the maximum benefit for the general public".

3. A national policy is needed to establish controlling standards, guidelines, and criteria for government agencies enforcing land laws.

4. Such guidelines for land use planning should require consideration of all possible uses,provide for the maximum number of compatible uses (but allowing where appropriate only one use to be dominant), prevent deterioration and encourage the improvement of environmental quality.

5. Finally the "maximum benefit of the general public should be interpreted as recognising at least the following six separate categories of interests within the concept of the general public:

> "-the national public: all citizens, as taxpayers, consumers, and ultimate owners of the public lands are concerned that the lands produce and remain productive of the material, social, and aesthetic benefits that can be obtained from them.
> -the regional public: those who live and work on or near the vast public lands ....(share the interests of national public but also) have a special concern that the public lands help to support them and their neighbours....
> -the Federal Government as sovereign: the ultimate responsibility .....is to provide for the common defense and promote the general welfare....(by) control of the public lands.
> -the Federal Government as proprietor:..... a land owner that seeks to .....exercise normal proprietory control over its land.
> -state and local government:.... have responsibility for the health, safety, and welfare of their constituents (and an interest in accommodating the Federal powers to local interest)....
> -the users of public lands and resources: users, including those seeking economic gain and those seeking recreation or other non-economic benefits, have an interest in assuring that their special needs, which vary widely, are met and that all users are given equal consideration when uses are permitted."
> (United States, 1970, p. 6).

How can we benefit from this experience in our policies towards our arid lands?.

The Australian Experience and the future challenge.

The challenge of arid Australia as considered in this paper has been twofold; first, the difficulties in establishing the nature of the arid resources - difficulties and a lack of knowledge which I suggest are still considerable - and the second resulting from the indifferent success with which humid-based land settlement systems have been transferred to the arid zone.

To attempt to meet those two challenges I make the following suggestions :-

1. Thought needs to be given to the survey and classification on a national scale of the resources of the arid lands. Many relevant studies already exist, but the results need to be compiled and standardised for comparative purposes and the gaps plugged. I define resources here, as did the American report, in their widest natural and human connotations.

The survey and classification should indicate guidelines and standards for the various uses, single or multiple, which may be possible and of particular concern will be the problems of potential conflicts between users (Fig. 6).

2. Thought needs to be given to the provision of land tenures more suitable to the environmental challenges of the arid lands. These challenges might be briefly identified as scarcity of good quality water, the abundance of solar energy, the low pastoral productivity per unit area, the high variability of pastoral production through time, the limited agricultural possibilities, the rich but remote mineral and aesthetic resources, and the abundance of unused space.

A combination of leaseholds and reserves seems to hold the greatest promise for the future, particularly when the optimum use is not yet certain. More specifically, these systems do allow controls of use which may be specially needed in the delicate arid zone ecosystem, where indeed the deterioration of the environment may be the price paid for <u>any</u> form of use (Campbell, 1966, p. 16) Indeed it may be found by such an investigation, that the emptiness of the arid lands is their most important resource - to be protected and not 'developed' by land tenure systems.

3. These two suggestions above could be most conveniently achieved by the creation of an <u>Australian Arid Zone Review Commission,</u> to be set up by the Commonwealth Government, but including representatives of all interested parties and state governments and whose task would be to :

(i) study existing statutes and regulations governing the retention, management, and disposition of the public lands of the arid zone of Australia.

(ii) review the policies and practices of the Commonwealth and State Government agencies charged with jurisdiction over the said public lands, insofaras such policies and practices relate to the retention, management, and disposition of those lands.

(iii) compile data necessary to understand and determine the various demands on the said public lands which now exist and which are likely to exist within the foreseeable future.

(iv) recommend such modifications in existing laws, regulations, policies and practices as will, in the judgement of the Commission best serve to carry out the policy of either a) retaining and managing or b) disposing of the said public lands in a manner to provide the maximum benefit for the general public.

4. In its work I would suggest that such a Commission might bear in mind that, currently, the arid zone of Australia remains one of the largest "empty" areas in an increasingly crowded world; that it has one of the largest untapped sources of pollution-free solar energy in a world increasingly polluted by fossil fuels; and that it has some of the largest and richest areas of relatively unspoilt natural landscape in a world becoming increasingly dominated by the "built-environment".

TABLE 1

AUSTRALIAN ARID LAND TENURES 1960s

State or Territory	Arid Land		Percentage of Arid Land			
	Area (Million acres)	% Total Area	Alienated	Leased or Licenced	Reserved	Unoccupied
S.A.	212	87	4.1	58.0	7.5	30.4
W.A.	539	86	0.6	47.9	6.8	44.7
N.T.	287	86	0.1	59.4	14.9	25.6
QLD.	268	63	0.9	97.8	1.1	0.2
N.S.W.	103	52	0.4	97.5	1.4	0.7
AUSTRALIA	1,408	74	1.0	64.9	7.0	27.1

TABLE 2

PASTORAL LAND TENURES IN THE 1960s

A. EXTENSIVE TENURES

Factor	State or Territory			
	QLD*	S.A.†	N.T.†	W.A.†
CONTENT	← – – – – – – – –	– Fodder and water – – – – – – – – – – – →		
TIME (years)	30	21 on new country 42 standard	50	50
SIZE (acres)	No limit	No limit	3,200,000‡	1,000,000‡
PERSONNEL	← – – – – – – – –	– No restrictions – – – – – – – – – – – →		
USE	Stocking liable to controls. Control of noxious weeds required.	Minimum and maximum stocking limits. Control of noxious weeds.	Stocking limits. Soil erosion survey possible.	Minimum and maximum stocking limits and continuous stocking required. Pasture management required. No agistments allowed.
	← – – – – – –	No agriculture without official consent – – – – – – →		

*Pastoral holding †Pastoral lease ‡Maximum allowed

B INTENSIVE TENURES

Factor	State or Territory	
	N.S.W.*	QLD†
CONTENT	← – – – – – – – –	– Fodder and water – – – – – – – – – – – →
TIME (years)	Perpetuity	Up to 30
SIZE	Up to 2 home maintenance areas	Living area‡
PERSONNEL	Personal residence on, or within 'working distance' of, for 5 years.	No agents corporations or partnerships of more than 2 persons. Personal residence for 7 years.
USE	Control of noxious weeds and vermin. No agistment without approval.	No agistment for more than 6 months in year. Control of noxious weeds.

*Western land lease, perpetual lease †Grazing selection ‡Maximum, 45,000 acres

Source Heathcote 1969b

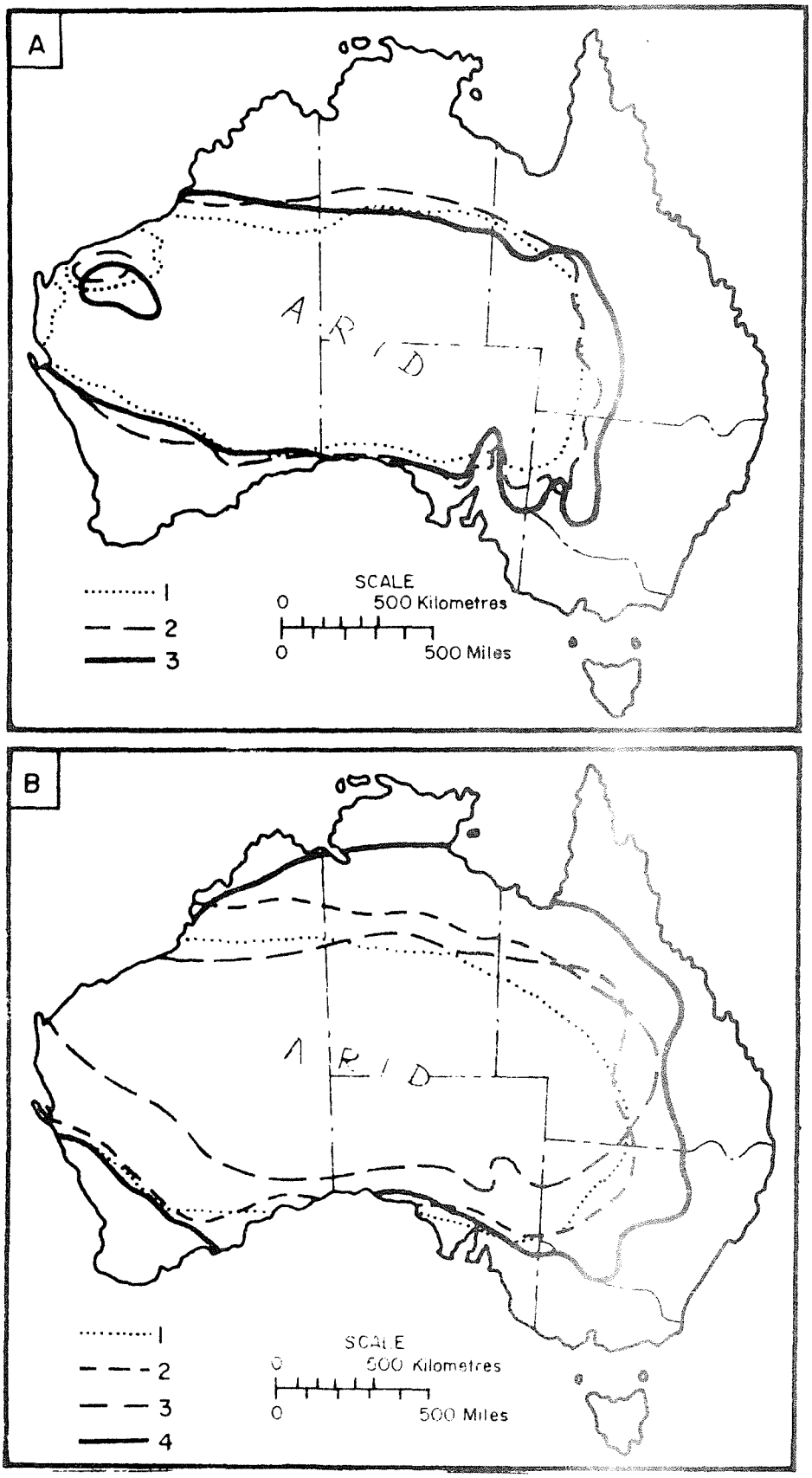

Figure 1. Climatological Boundaries of Arid Australia

Figure 1. Climatological Boundaries of Arid Australia.

KEY. MAP A

1. Koppen's"dry region" 1931.
2. Thornthwaite's "arid region" 1931
3. Meig's "arid" region (UNESCO) 1953.

MAP B

1. De Martonn's index of aridity ($\frac{P}{T+10}$ = 10) 1927.
2. Andrews and Maze's arid border of eight months when $\frac{P}{T+10}$ = less than 1, 1933.
3. Davidson's "desert" with no month with $\frac{P}{E}$ greater than 0.5, 1936.
4. Perry's limit of rangelands 1967 for comparison.

NOTE : P = precipitation: T= temperature; E = evaporation.

Sources Marshall 1948, Meigs 1953, Perry 1967.

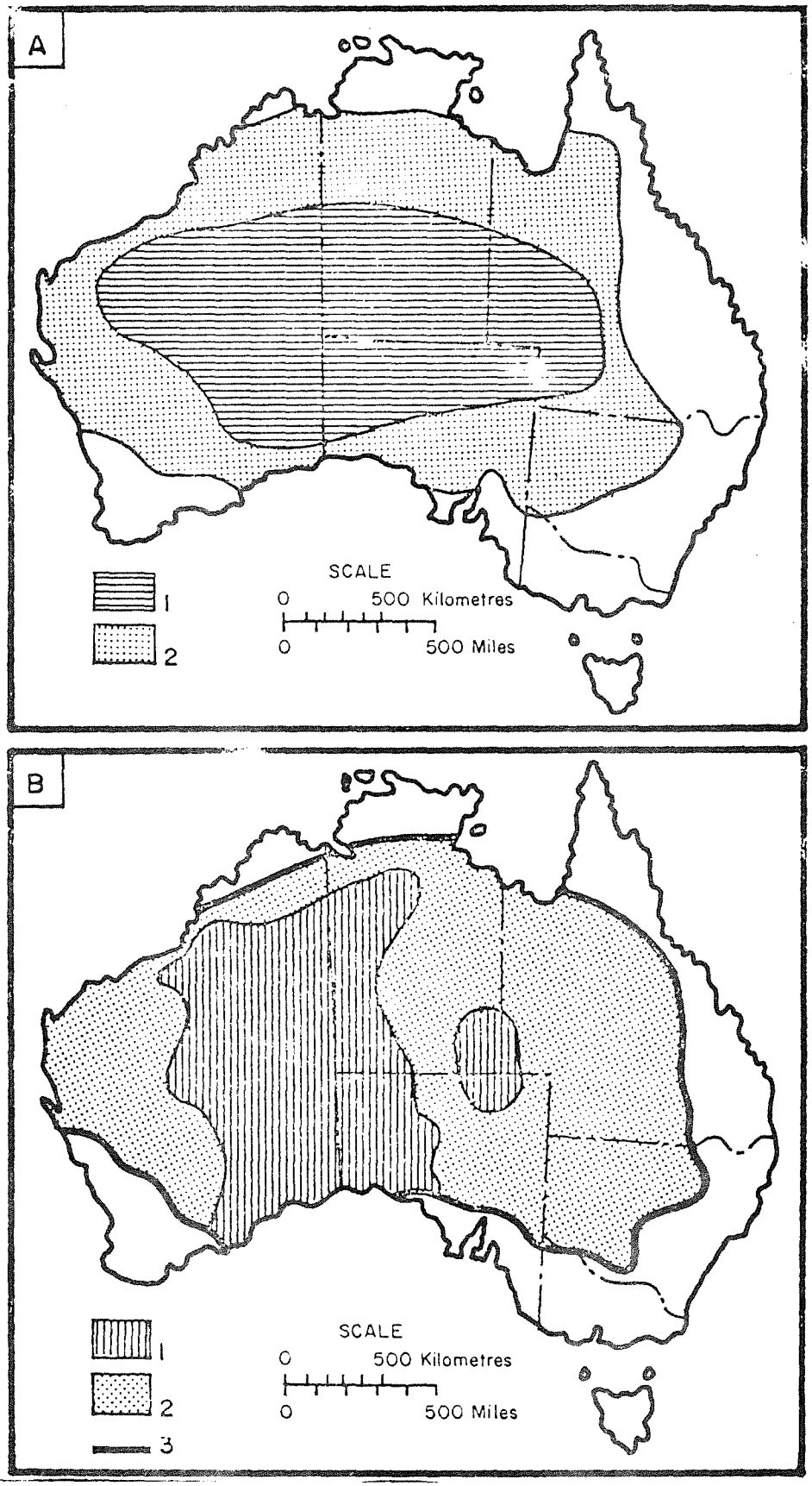

Figure 2. Geographical Boundaries of Arid Australia

Figure 2. Geographical Boundaries of Arid Australia.

KEY. MAP A

1. Growing season of less 1 month.
2. Growing season of 1 to 5 months.

NOTE : Growing season = $P > 0.4E^{0.75}$. P and E as Fig. 1.

MAP B.

1. Unoccupied land within arid zone.
2. Pastoral lands within arid zone.
3. Limit of arid zone.

Sources CSIRO 1968-69, Davidson 1967, and Prescott and Thomas 1949.

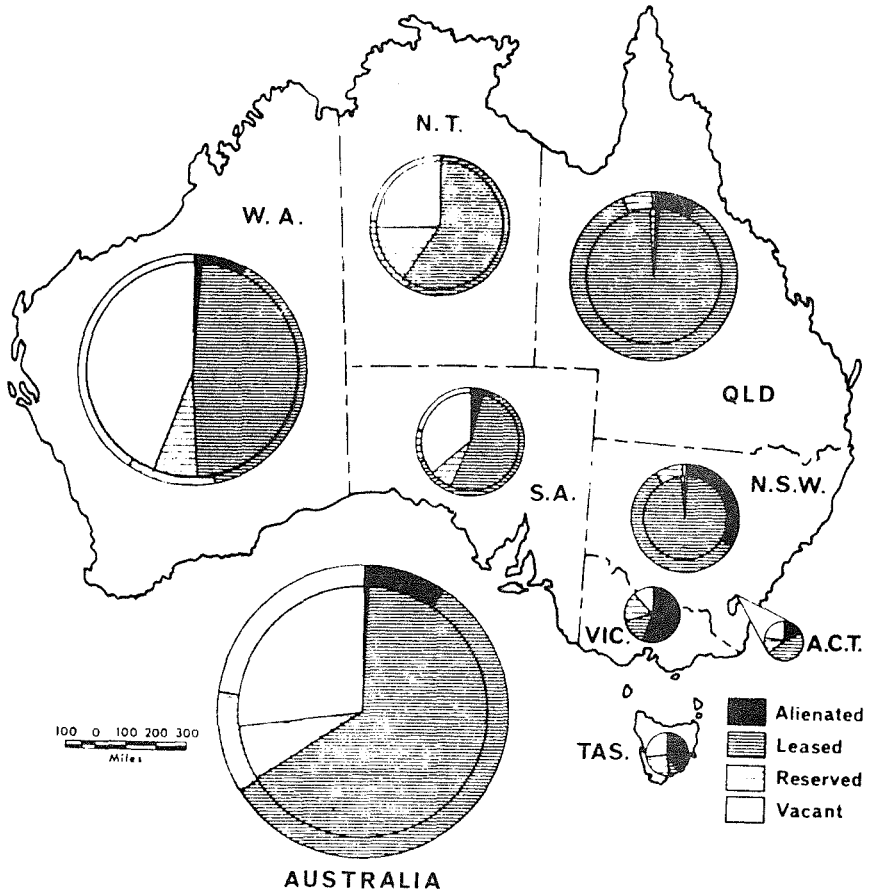

Fig. 3 Australian Arid Land Tenures in the 1960s

Inner circles show proportions of arid lands under various tenures; outer circles show the tenures for the whole state, territory, or Commonwealth.

Source Heathcote 1969b

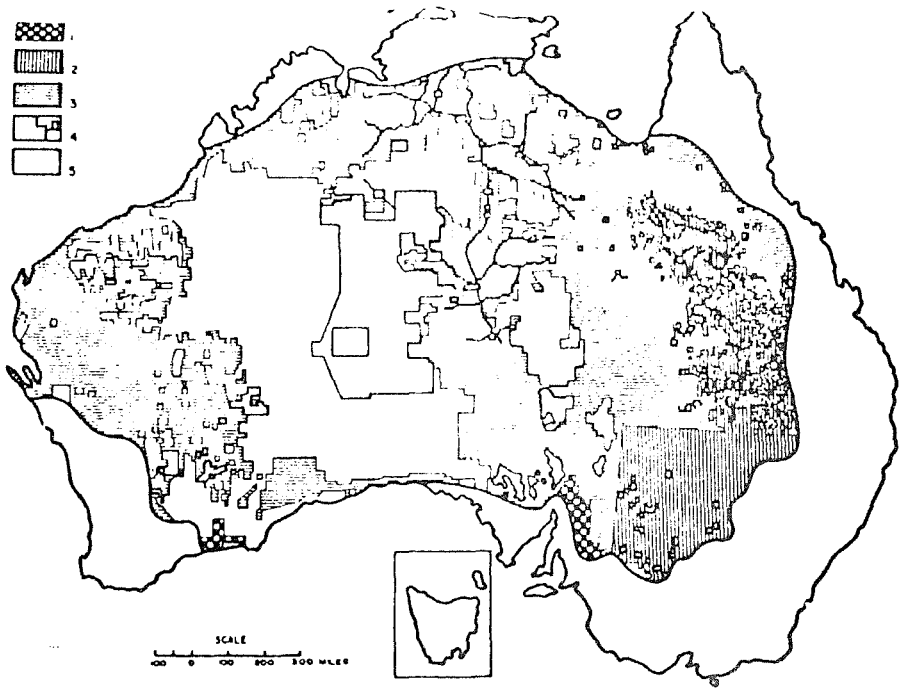

Figure 4 The pattern of Australian arid land tenures in the 1960s

Figure 4. The pattern of Australian arid land tenuresin the 1960s

Key: 1 - Alienated land. 2 - 'Intensive' leases (pastoral leases where the size of individual leases is limited in terms of 'living' areas). 3 - 'Extensive' leases (pastoral leases with no size limit related to any 'living' areas, but which may have a ceiling to their possible size - see Table 2). 4 - Reserves. 5 - Vacant land. Note that mineral rights and leases are not shown on this map.

Sources: This map is generalised from an original at 1:4,500,000 derived from sources lited in Heathcote, 1969b.

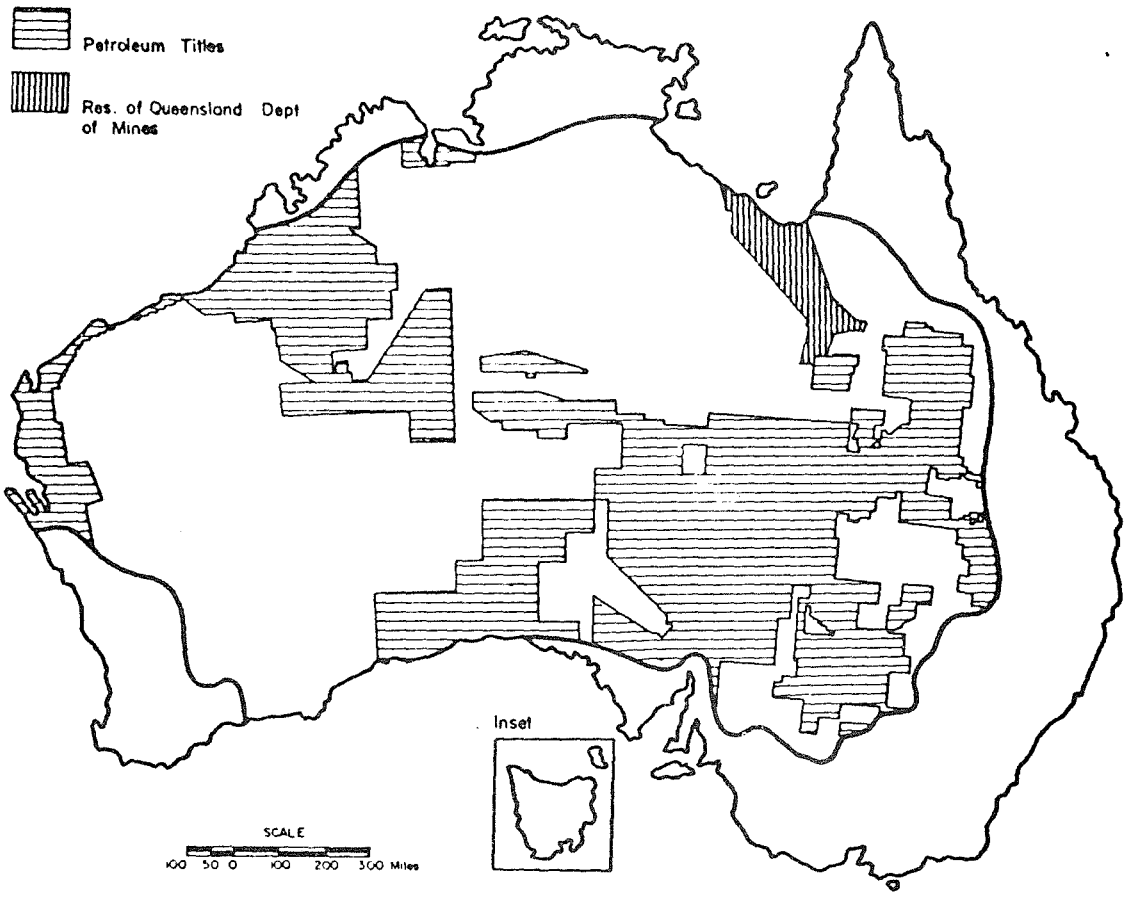

Figure 5. Petroleum titles in the arid lands 1968.

Source: Map of 'Petroleum Exploration and Development Titles, 30th June 1968'. Commonwealth Bureau of Mineral Resources, Geology and Geophysics, Canberra.

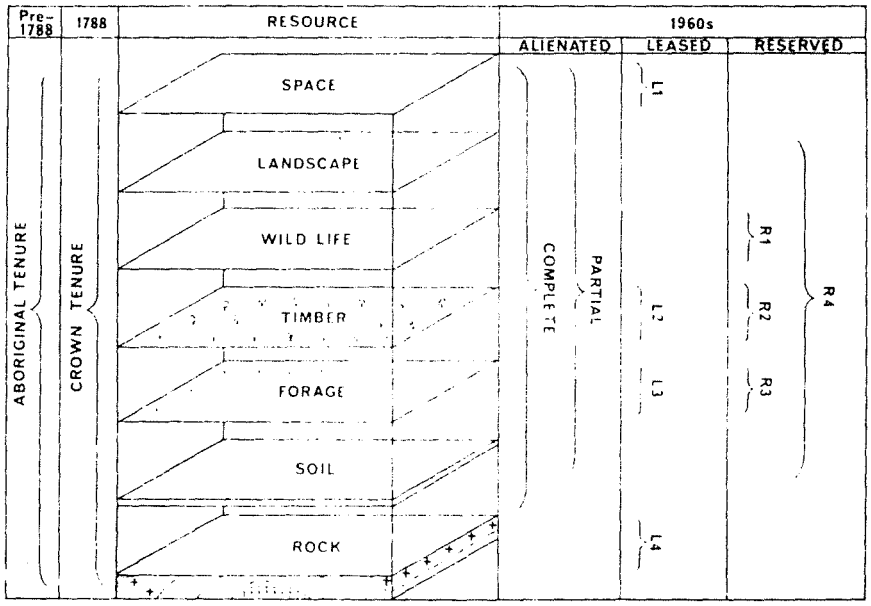

Fig. 6 The Framework for Arid Land Tenures

Note: The range of resources covered by Aboriginal, Crown, and contemporary types of land tenure is indicated. Initially, post-1788, alienation covered the complete range of resources, but since approximately mid-nineteenth century the alienations have excluded rock and mineral rights. Examples of leased tenures: L1—military leases; L2—timber licences; L3—pastoral leases; L4—mineral leases. Examples of reserved tenures: R1—fauna protection; R2—forest reserves; R3—travelling stock routes; R4—national parks.

Source: Heathcote 1969b

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NEW ATTITUDES TO LAND USE IN OUR ARID ZONE

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This is a complicated topic, made more so by loose terminology and evasive thinking. What constitutes an idea, a viewpoint, an attitude to land use? I use some arbitrary and ruthless definitions about this.

Let us say that our actual use of arid lands bespeaks our society's attitudes, and that our thoughts not translated into action and reality are our viewpoints and ideas.

Then, if we make laws against littering, and if each of us professes the viewpoint that we are against littering, but our landscape continues to be littered with refuse, this definition says our society's attitude is that landscapes shall be littered with refuse.

You see how this definition brushes aside communal and individual statements of good intention, to look at the sometimes unpleasant reality.

From the landscape's point of view (if it can be said to have one), it is nett physical impact alone that matters. Words per se mean nothing to it, nor are the niceties of minority opinion or individual excuse remotely relevant. Things happen to it at the hands of our society, and that's that. We are known to landscape and to its history only collectively, and by our deeds alone.

Let us now lead up to the question of our new attitudes (there are some) and our ideas and viewpoints (there are lots of these, but not many are new), first getting our context sorted out by examining some of our old attitudes.

Perhaps our first attitude to South Australia's arid lands was that they were places to explore geographically and write books about. I think more books have been published about this than about how to manage the place. A further early attitude was that the aboriginal inhabitants should be displaced and their opinions disregarded.

But our first major attitude, and our main enduring one, was that these lands serve for pastoral enterprise. By the mid 1950's, pastoralism had spread into the margins of our northern saltbush - bluebush country, and people realized that merino sheep would do very well there if properly provided with water. N.A. Richardson[1] described the early stages of this pioneering. Then in the next decade (see A.E.V. Richardson[2]) the industry drove right through to Alice Springs with cattle, between the Simpson and Victoria deserts, and took up the essential land-use configurations seen today as pastoral lease.

This attitude of exploitative pastoral enterprise was to persist and become part of our way of life, but not without prompt dissenting viewpoint, which I record to remind you that the conservation viewpoint, the ecological - environmentalist viewpoint, has been with us throughout our history.

Dixon[3], already in 1892, had this to say:

> ".. and to the extreme western and northern runs of South Australia, the injury to the original vegetation by over-stocking has assumed so great a magnitude as to entail a national loss."

And further, about landscape resources generally:

> ".. very extensive forest-reserves ought to be set apart in such a manner as to be beyond the possibility of resumption by the political heads of the Crown Lands Department of each colony, whose fiscal necessities have frequently caused the public estate to be alienated for the benefit of private individuals."

When I further point out that the nineteenth century saw vigorous agitation for the protection of native fauna, for creation of nature reserves, some might say that things haven't changed much.

Another major old South Australian attitude to arid zone land use is intermittent. It has a habit of recurring. Bowman[4] expressed the essence of it:

> "A desert in Australian politics is something hot and plantless that exists somewhere in the world but not in Australia."

This attitude stems from the viewpoint that we must, somehow or other, bring the arid into production by farming.

Let us therefore recall some of the Goyder[5] case-history, which epitomizes its sequels and the obtuse nature of our collective behaviour.

In 1865, droughts severely affected those northern pioneer pastoralists and the government, moving to aid them, directed the then Surveyor-General, Goyder, to

> "determine and lay down on a map, as nearly as practicable, the line of demarcation between that portion of the country where the rainfall has extended, and that where the drought prevails."

This he did, and the episode closed, except that Goyder and others came eventually to the idea that his line separated two very different potential land use regimes.

Years later, hard pressed to keep government surveying abreast of the rapidly expanding wheat frontier, Goyder saw the phenomenal wheat-field expansion approaching his line, and warned against its transgressing it.

His warning was not received sympathetically by the wheat frontiersmen and the like-minded. They had the magic word - progress. Goyder was variously rubbished and, to some extent, deliberately discredited. Some of science or at any rate learning joined the frontiersman attitude of "rain follows the plough", with tree planting programmes to improve the rainfall. With calls for

> "... doing away with Goyder's absurd line of rainfall..."

Parliament in 1874 opened the whole of South Australia for credit selection.

Well, Goyder was right so far as predicting consequences was concerned, and farming in the arid areas failed catastrophically. Immediate losses were enormous, enduring losses to the State can be seen today in the condition of the "marginal lands", that blank strip on the Pastoral Map of South Australia, between the black of the agricultural railways mesh, and the red of the pastoral lease boundaries. Immediate experience taught the meaning of "arid-zone" - a place where it is not possible to live by growing non irrigated sown crops, on account of inadequate rainfalls. In view of repeat performances from time to time, one wonders if we will ever learn the lesson. Sadly, expert advice usually lacks the appeal of Ernestine Hill's inexpert viewpoint:

> "Ten thousand people are holding the land that could make room for 50 million..."

Well, thus far we have such old South Australian attitudes to arid zone use as (all by my special definition);

- Its aboriginal inhabitants shall be displaced, but parts of the zone shall be aboriginal reserves.

- It shall be stocked deliberately, where practicable, in the South by sheep, without any praise for those conscientious pastoralists who care for it, or much censure for the careless ones, and to the north by cattle which shall strip the place of each successive batch of herbage.

- It shall be stocked fortuitously with alien plants and animals, to the decimation and near extinction of numerous native animal populations.

- Attempts shall be made to farm its fringes from time to time, despite expert advice against doing this.

To these might be added such other old South Australian attitudes as follows (up to say, a decade ago).

- The most barren parts shall remain unalienated.

- The mineral deposits shall be sought out and put to our use.

- Minor industries and events of a spontaneous sort shall be accommodated (timber getting for pit-props, fencing, sandalwood; Kangaroo shooting, rabbiting, sets for films about drovers and bushrangers, subjects for painters and authors, and speed record attempts on saltpans).

- Part of the place shall be used for testing a british atomic bomb, more shall be used for a rocket range.

The foregoing, give or take a bit, amounts to our demonstrable old attitudes to land use in our arid zone.

Now, what about our new attitudes, do we have any? Indeed yes - few and new, but most significant.

First, we have the revised attitude that mineral deposits shall be sought out with a vengeance, as a priority matter. Enormous capital inflow and effort is now being expended within the zone in this attitude, with all sorts of spinoff starting to affect land there.

Second, we have the beef road - motor transport attitude, with the landuse spinoff that agistment and restocking can better adjust stock numbers to good and bad seasons - a power to save or finally destroy inland vegetation, depending on how used.

Third, we have the very new attitude that parts of the place shall be dedicated as national parks and wildlife reserves, not perhaps as inviolate as Dixon would have liked, but reserves neverthe less.

Fourth, we have the attitude that organised tourism has its place in land use. This has already registered on the landscape in ways both good and bad.

Fifth, we see a slight attitude for more cattle on sheep country inside the dog fence.

And now to conclude. I need hardly remind you that our society has rarely been so worked up about ecology and environment - at the level of ideas and viewpoints. Society in most affluent "western" countries is: even Donald Duck comics (yes, I read them) plug the conservation theme. The point I want you to note is that (with one or so notable exceptions) our arid land hasn't noticed much actual fallout from our fervour yet. In fact fallout (of the french radioactive sort) and the presence of some stock and vermin, is about the only way the tynical hectare of our arid land now registers man's existence.

Do I anticipate some further new attitudes? Yes indeed. I worry that the remoteness factor might appeal to those with toxic things to dump, and nasty things to hide - not the sort of land use Dixon or I would like made of the arid. I anticipate that the pastoralist attitude will eventually lapse of necessity on carelessly tended leasehold, because the vegetation will, and will properly persist, on carefully tended leasehold. I think the tourism attitude may grow, hopefully along with the wildlife reserve attitude (both have high potential as ecologically tenable land use systems - a potential sadly lacking in say, the bomb test site attitude). And I anticipate an attitude that will pass some of the zone back to its original dispossessed owners.

As to the big questions - how will arid zone land use attitudes relate to the Z.P.G. - feed our billions issue? - how will arid zone land use relate to the maybe power sources of the future? The first answer must come from the field of humanism[6], the second from science of a different sort to mine.

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THE PROSPECTS FOR TOURISM

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In assessing the prospects for the development of Tourism in arid areas and endeavouring to determine whether any such development, to use the words of your State Chairman, Mr. Bonython - "Could provide a continuing source of wealth without threatening the landscape resources" - poses a number of very complex questions, may of which I would be far from qualified to even venture more than an opinion, and not a very authoritative opinion at that.

For example, one would be somewhat rash in these economic times to guarantee a "continuing source of wealth" - and I certainly couldn't make any definite promises to my old friend Dick Piesse regarding "threatening the landscape resources".

Hammond Innes in his recently published book entitled 'Introducing Australia' states - "Australia is unique. It is extraordinary. Most of it is desert. The uninhabitable four-fifths of Australia is old geologically, very old - and it is flat. The distances in Australia are not enormous but the myth of Australia as a big country remains. It is not distance that makes it so, it is the inhospitable nature of the terrain." - Not the most encouraging remarks, particularly when related to the prospects for Tourism.

However, in fairness to Mr. Innes, he also had this to say - "The sea may call for recreation - it is on the doorstep of every city - but for adventure, it is the interior, the CENTRE, the red, inhospitable desert that calls, the remote, fascinating, for most not-to-be attained World of salt lakes, spinifex, mulga and ghost gums. A World for which AYERS ROCK has become a symbol - in the same way that the Barrier Reef epitomises all the strangeness of the Sea" - in these words, the infusion of adventure provides a platform for the possible stimulation of successful Tourist development, in at least some of our arid areas.

Tourism, or put another way, travelling for pleasure, is an old industry, and yet as far as Australia is concerned, it was as recent as 1964 that the first comprehensive survey of the travel and tourism industry of our country was commissioned by the AUSTRALIAN NATIONAL TRAVEL ASSOCIATION (now the AUSTRALIAN TOURIST COMMISSION). I make mention of this, to emphasize the comparative youthfulness of what could be termed the professional approach to the Industry in Australia. This first report, by Harris, Kerr, Forster and Company and Stanton Robbins and Company Incorporated, both U.S.A. Consultants, recognised for their studies in transportation, tourist and recreational development, virtually became the blue-print for Australia's subsequent tourist development.

Late in 1968, the Australian Tourist Commission again commissioned Harris, Kerr, Forster, together with associated companies, to present a TOURISM PLAN FOR CENTRAL AUSTRALIA embodying a special report for the Northern Territory Reserves Board outlining a DEVELOPMENT PLAN FOR AYERS ROCK - MT. OLGA NATIONAL PARK. During July-August, 1970, the AUSTRALIAN NATIONAL TRAVEL ASSOCIATION undertook an appraisal of the PILBARA region and their recommendations were contained in a report published in January, 1971.

I make mention of these activities, merely to make you aware of the attention that has been given to the development of Tourism, in what could be termed arid areas, although I appreciate that certain sections of the PILBARA region would not necessarily qualify as arid.

However, whilst these various plans and recommendations provide excellent guide lines for future development, a large part of the success of any tourist development will depend on all involved parties understanding the economic and cultural benefits Tourism can offer, and the value of coherent planning and programming of the over-all developmental project.

The Leader of the Federal Opposition in a recent speech to the Surfers Paradise Chamber of Commerce stated - "Tourism can contribute to the solution of our national problems in ways of which, as yet too few Australians are aware - however, it demands national vision and finance."

There must be a realization that the product components of the Tourist Industry, and I stress, Tourism is an Industry, must be assessed with the same stringent business principles as are applied to development projects in any other Industry.

Nature has provided many base product components of Tourism, gratis, but even so, these base products must be evaluated, in the light of the developmental costs necessary to produce an end product that has tourist appeal and is a viable economic proposition.

It cannot be denied, to use the words of the Chairman of the AUSTRALIAN TOURIST COMMISSION that "there is a consciousness that the scope for new initiatives and new developments is extensive; Tourism is a rapidly developing and dynamic Industry and much needs to be done".

I am in complete agreement with this statement, but I would point out that, whilst the scope for new initiatives and new developments is undoubtedly extensive, the competition is exceedingly keen. Therefore, in assessing the prospects for Tourism in arid areas, all the factors "for and against" must be weighed very carefully against the "pluses and minuses" of other developing areas.

Such an "in depth" study should answer four important questions -

(i) What have the arid areas to offer tourist wise?

(ii) The amount of developmental capital needed.

(iii) What is the likely return on investment both short and long term?

(iv) The share of the Tourist Market you must attract to service the capital investment.

On the subject of developmental capital, and particularly in relation to arid areas, I submit that Government should accept a far greater responsibility by undertaking the primary development (e.g. provision of all weather access roads and airports, where applicable, essential services such as, water, sewerage, power, communications, etc., create more National Parks and the further development of those in existance, the preservation or creation of things Australian).

Personally, I see the overall problem of successful tourist development being best tackled by a planned approach - marshalling the resources of both the public and private sectors of the Industry, whereby Government undertakes the initial development and private enterprise the secondary stage.

Alternatively, if Government chooses not to accept these responsibilities then incentives should be made available to Industry to stimulate and attract tourist development. Despite repeated representations to the Commonwealth Government on the matter of public assistance, in the form of Tax concessions, depreciation allowances, Tax free grants, low interest loans, etc., the majority of these submissions have been unsuccessful, despite the fact that there is sufficient evidence to suggest that such action by countries in other parts of the World have stimulated the profitable development of Tourism.

Most of the recommendations contained in the Surveys I have referred to earlier in this paper had the broad objectives of encouraging more Overseas visitors, but considerations were also given to the needs of the domestic market, as for many years to come, if not forever, the Australian Tourist will provide the foundation and framework on which any tourist development must be structured.

The Australian Tourist represents an enormous market potential, even in the case of arid lands, but I suggest he is not always easily identified, and his considerable economic contribution to the Tourist Industry goes unnoticed.

A tourist is generally considered to be a vacationist, or one who is travelling for pleasure. However, I contend the word 'Tourist' means any one who travels away from home whether for a day, a week or whatever period. Whilst it may be true that the vacationist of pleasure traveller represents the largest proportion of tourists, even the business traveller can at times be persuaded to become a tourist.

For example, of those of you from Interstate who were in Adelaide during last week-end, how many, say, visited Victor Harbour, the Barossa Valley, the Botanic Gardens, etc. -- if you did, you were a tourist, and monies you spent during your visit to any of these places contributed to the economics of the Tourist Industry.

The Tourist Industry comprises a number of inter-related enterprises, providing for the needs of the tourist. Some of these vital components in this inter-relation, other than Transport Companies such as Ansett, are hotels, motels, caravan parks, restaurants, stores, gift shops, garages, automobile clubs, tourist promotion agencies and the physical facilities of the region itself, to name but a few.

I mentioned previously the need for an understanding of the economic and cultural benefits Tourism can offer, but I submit that, before understanding can be attained, it is first necessary to have an awareness of the multiplicity of activities which are affected indirectly by the travel and tourist movements. They would include almost every business and service activity related to people away from their homes.

An acceptance of this awareness will make for a more representative and stronger Tourist Industry, facilitate development, engender economic growth, and above all, ensure tourist satisfaction.

The private motorist, with or without caravan, represents by far the greatest number of Australian Tourists, and each year, they are journeying further afield, crossing the Nullarbor Plain, tackling the Birdsville Track, and arriving in "Alice" from north, south east and west!

Surely, with the gradual improvement of our road systems to and within tourist destinations, more and more motorists will become adventurous and this should auger well for the prospects for Tourism all over Australia, including the arid regions. Not only will the ultimate tourist destination benefit, but en route towns will also enjoy a share of the tourist dollar from the passing traffic. Since the increase in vehicular traffic from Adelaide to Alice Springs, I wonder just how much, say, Coober Pedy has benefited from the Tourist Industy?

It has been said that if there's a road leading in and out of a town, there's a fair chance of attracting tourists; all that is required is to recognise tourist assets that are hidden in the town and are not being used, or that need developing. Hidden tourist assets may be much more valuable than those on the surface; an inventive approach in searching through historical records and the use of imagination in assessing a town's natural or man made attractions, is all that is needed.

Philip Schrapnel & Co. Pty. Ltd., economi consultants who were commissioned by the Federal Government in December, 1969, to analyse the factors affecting past, present and future growth of Darwin and Alice Springs and to assess future trends, had this to say of Alice Springs - "By 1985, Alice Springs could be larger than Darwin is now, so there is the further prospect that it would then be big enough to attract capital inflow not merely from nation wide retail and wholesale traders, but, also, from Banks, Insurance Companies, and some Manufacturers. When this happens, its long term growth could acquire a new dimension that is at present lacking. <u>However, without Tourism, none of these things would be as likely to occur, and the development of Tourism offers the best prospect of transforming this relatively small urban centre into a large one".</u>

No matter where the town or tourist destination is situated, Tourism can make a contribution. Admittedly, in the arid regions of our land there are problems to be overcome which may not exist in other areas, but with modern technology and the infusion of capital, plus the excellent tourist

surveys which have already been carried out in some of the arid regions forming a basis for tourist development, I can see no reason to be pessimistic regarding the future prospects for Tourism.

WILDLIFE AND PEOPLE

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I have permission from the organisers of this symposium to treat the title in any way I like. Therefore, I would like to change it to "Man and other Wildlife" ! With this viewpoint I hope to give you a different slant on the interactions of wildlife and people which will have implications for our arid zone fauna.

Let us go back to when all the problems commenced, to the onset of the Pleistocene (about one million years ago). Evolution during the Pleistocene produced all sorts of new genera and species, some very specialised and some huge. From among the great apes in Africa evolved one highly successful species whose very success depended on its non-specialist adaptability. Man evolved with the Pleistocene fauna of Africa and it is postulated that the reason Pleistocene forms such as elephants, giraffes, etc., were not wiped out by man in Africa was because they evolved defensive, adaptive patterns and were at a prey/predator balance with the most skilful hunting animal the world has ever known. The unadapted Pleistocene fauna of the rest of the world collapsed at different places at different times. The times coincided with the invasion of man and the process was called "Pleistocene overkill". Following the arrival of Homo sapiens in Europe 250,000 years ago animals such as the elephants and hippopotamus disappeared. However, the impact on the American fauna was much more dramatic. The earliest Amerindians reached North America about 30,000 years ago. Since then one half of the mammals identified as fossils in the Los Angeles tar pits and one fifth of the birds became extinct. Mastodons, super camels, the teratorn with 17 feet wingspan and many others disappeared with the advent of the sophisticated flints of the Clovis and Folsom cultures. Such flints were quite adequate to kill and butcher an elephant. The Polynesians discovered the New Zealand islands about A.D. 950. Before Captain Cook arrived 20 species of moas were already exterminated and the last species was killed out in the 18th Century. Many of the other strange island-adapted animals disappeared in this period.

Many species die out because they cannot adapt to changing conditions and so become extinct or in fact sometimes change into other species if they can adapt. However, most of the Pleistocene extinctions cannot be attributed to this as fossil records show that the "life" of bird species is usually over 2,000,000 years and that of a mammal species about 600,000.

The year 1600 is the earliest date from which we have reasonably accurate records. Of the 4,276 species of mammals living then over 40 have become extinct, and at least 120 are in danger. There were approximately 8,684 species of birds in 1600 and of these about 100 have disappeared and nearly 200 are dangerously rare. The extinction or rareness of about 75 per cent of these species can be attributed to human activities of hunting, introduction of predators and competitors, habitat disruption and simply their destruction as pests.

I once had to review The Red Book (from which some of the above information was cited). I was able to write that the Mexican Grizzly Bear which was stated in the book to be in danger had been exterminated by a successful 1080 campaign by the time the book was reviewed.

Let us turn to Australia. Stone Age man invaded Australia several times starting about 13,000 years ago. He brought with him his yellow dog and since then it is coincidental that the huge diprotodonts have gone, the giant wombat and kangaroo. Cave deposits show the Thylacine to have disappeared on the mainland about 3,000 years ago. Possibly this was due to competition with the dingo. We all hear of sightings of "tigers" but until someone obtains one dead or alive I remain unconvinced.

Apart from rodents which have introduced themselves by travelling on rafts of logs the dingo was the first introduction by man. Among the colonists arose several active "acclimatisation societies" which introduced everything from nightingales to ostriches. The hunters brought in foxes and rabbits. Eric Rolls in his excellent book "They All Ran Wild" describes the rabbits as the grey blanket. Their ravages caused vast habitat changes. Whole vegetation complexes disappeared producing instability and erosion. The effects of this on wildlife can only be guessed at as can the numerous introductions made to eat the rabbits ! There were weasels, stoats and cats; the latter were released on the western plains in batches of 250. They no doubt all ate their share of native fauna and still do. I have seen cat tracks everywhere in the bush, even far out in the dry country. One woman writing to me in desperation concerning their depredations on the birds in her garden referred to them as "pestilential preyers" and "silent springers". Digressing on the subject of pets, we are all brought up to love pussy cats and puppy dogs. As suburbia spreads into the bush like a cancer it takes with it these parasites of man. The cats can be exceedingly skilful hunters of native mammals and birds while dogs always "enjoy a run in the bush" and in the process terrify or kill an odd wallaby, bandicoot or echidna.

Let us return to the rabbit problem. Every known poison on every sort of bait was spread across the countryside. There are records of considerable mortality among native fauna but the survival of man and his flocks was at stake so nothing else mattered. The story of myxamatosis does not need retelling here and this virus is still reasonably effective. However, the poison 1080 is being used on a wide scale and many people have misgivings about this. At times these fears are justified when farmers or government employees act carelessly or irresponsibly. However, to date, it seems the best poison because many of our native animals are partially or wholly immune to its effects. Perhaps this is because it occurs naturally in some native plants. Emus are quite immune to it; it takes a good dose to kill

a kangaroo, while possums and blacktailed wallabies seem susceptible to it. There is a lot of work to be done on 1080 and wildlife. Wildlife departments do not do it because they fear adverse publicity and vermin control agencies are too busy getting on with the job. However, this is important work because as the effectiveness of myxomatosis wanes, as it must, poisons will have to be used more extensively if the pastoral industry is to survive and precious wildlife habitat is to be preserved.

Homo pastoralensis ! What an effect this species has had on wild life by mismanagement or rather mistaken management of our country - especially in the sensitive dry country. One gentleman received a knighthood for his efforts which sent a large portion of South Australia to New Zealand by air in the form of red dust and in the process ruined the habitat for thousands of hopping mice and other wildlife. The sheep were alright in those days as they were merely moved on to the next lease. Clearing and grazing of our inland grasslands has replaced the long grass species with a short sward. Pigeons and parrots that depended on the grass seeds have gone, so have animals which used the Boree scrub and salt bush. However, wood duck, stubble quail and the red kangaroo have increased and for them things have never been better. In the north-west where I worked for a time the story was the same. Overgrazing and burning in winter produced a complete vegetation change. A place where hay was once mown called "Grassey Flat" grew only buck spinifex which would go through one's boot. However, the euros or hill kangaroos prospered. Much of the good grassland was replaced by soft spinifex and the euros thrived on this. This country is being restored by controlled grazing and burning in summer when fires are usually started by lightning.

This brings me to subject of fire, one of man's earliest discoveries and tools. It is ironical that modern man's prevention of fire has actually caused the rarity and sometimes extinction of wildlife. For example, heath is an early seral stage in some plant communities and is in time replaced by other species if the succession is uninterrupted. In North America rigorous fire prevention caused the extinction of the heath hen and it was realized too late that a good fire would have regenerated this bird's ideal habitat, heathland. The rarity of our eastern ground parrot is attributable to heath being replaced by Melaleuca because burning is retricted. Now modern game managers use fire to produce the required habitat. Burn a certain forest once and a dense Acacia scrub will result. This is good for bronze-wing pigeons and black-tailed wallbies. Burn a second time before the Acacia has seeded and only grass will come up, but this suits the grey kangaroo.

Has man changed much in 100,000 years or has he only replaced the flint-tipped spear with the soft-nosed bullet? Perhaps we have some room for optimism. Some people replace the soft-nosed bullet with a camera. There are some sanctuaries and national parks,

although not enough. Conservation is almost an "in thing" and with a depressed pastoral industry it is easier to reserve land. Private sanctuaries are being created. Thirty of us in Melbourne have bought 300 acres as a residential sactuary. The residents will manage the habitat and act as game wardens. A slightly different scheme conserved some habitat for the hairy-nosed wombat in South Australia.

What of the arid country and its wildlife and people? This sort of country requires huge areas as sanctuaries with proper habitat management to restore them. However, so much of this country has changed that perhaps we should use it as it is. The artificial water and short grass constitutes ideal red kangaroo habitat. The species has adapted its breeding to the erratic inland rainfall and requires a less nutritious diet than the sheep to maintain normal growth which is slower than in the sheep. It is known that kangaroos and stock do not have identical food preferences so the inland can be managed to produce the maximum amount of protein for a protein-hungry world - for the humans, not the cats and dogs. All states are trying kangaroo management schemes of one sort or another and if they can be made to work to advantage of the pastoralists he may forget his longstanding hatred of the kangaroo. Perhaps then the people of the inland can have a reasonable and productive relationship with its wild life.

RESOURCE SURVEYS IN THE CENTRE

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The Australian arid zone extends into all of the mainland states. For the purposes of this paper, I have confined my attention to the arid southern part of the Northern Territory; the area south of Tennant Creek commonly known as "The Centre".

Resource surveys in the Centre have been concerned primarily with pastoral activity (Webster, 1958; Perry, 1962; Stewart, 1968) or with mineral exploration (Wells, 1969) though each has recognised the presence of the other and the presence of the tourist industry in the Centre.

EXPLORATION, SURVEY AND SETTLEMENT, 1860 - 1939.

The period 1860 to 1939 was an era of exploration, survey and settlement in the Centre. Explorers were sponsored by pastoralists, governments and mining interests and were seeking new grazing lands, a route to the north-west and mineral deposits. The surveyors who followed added to the geographical knowledge of the Centre.

The explorers and surveyors of the period were not trained resource surveyors and their diaries were often written with more emotion than scientific detail. However, they initiated development in the Centre and were able to return botanical and geological samples for identification.

Foremost amongst Centralian explorers was surveyor John McDouall Stuart (Stuart, 1863; Webster, 1958) at a time when the South Australian Government was actively promoting exploration and settlement in the Centre by offering rewards, under certain conditions, for journeys which opened up new pastoral lands. In 1859, the South Australian Government offered an additional reward of £2,000 to the first person to cross the Centre to enable a telegraph link to be made from Adelaide to the northern shore and on to India. Stuart left a northern South Australian station on 2nd March, 1860 and by 23rd April he had passed through the MacDonnell Ranges and reached the geographical centre of Australia, Central Mount Stuart.

Stuart made three trips through the Centre before reaching the northern shore, and his diary contains frequent notes on the land resources. Of the MacDonnell Ranges he wrote, "The country in the ranges is as fine a pastoral hill country as a man could wish to possess - grass to the top of the hills and an abundance of water through the whole of the ranges". Naturalist F.G. Waterhouse joined Stuart's third journey through the Centre though unfortunately his records are not available and his report to Parliament contains only brief mention of the Centre.

Over the next twenty years the country to the west of the telegraph line was explored by Giles, Warburton, Gosse and Tietkens (Giles, 1875; Warburton, 1875; Davenport, 1886; Favenc, 1908). Ernest Giles recorded the waterholes, springs and grazing lands which, a few years later, were to become the areas initially developed on Glen

Helen and Tempe Downs Stations. Giles diary reflects the difficulties the explorers had with pack animals and their preoccupation with locating sufficient water to ensure the survival of their parties. Surveyors Barclay (1916, 1930), Winnecke and Lindsay explored the country east of the telegraph line.

The Horn Expedition of 1894 was the first scientific resource survey of the Centre. It was a common belief at the time (Horn, 1896) that when the rest of the continent was submerged, the elevated portions of the MacDonnell Ranges existed as an island, and consequently older forms of life might be found in the more inaccessible parts. Interest in the Centre was further aroused by travellers' tales of the plant and animal life in the region. The aim of the expedition was not to explore a new region but to survey the main routes of Stuart, Giles and Gosse through the MacDonnell Ranges in much greater detail (Spencer, 1896).

The expedition did not find an oasis of primitive fauna and flora but was able to make a systematic survey of the plant, animal and geological resources of the Centre. From the botanical collection of over 600 specimens, Professor Tate (1896) recorded eight new species and 112 species not previously recorded in the Centre. Professor Tate and Mr. Watt (1896) were able to review the geological records of the Centre and correct several recordings by less authoritive explorers.

Following the transfer of responsibility for the Northern Territory from South Australia to the Commonwealth Government in 1911, a progressive policy of resource survey and development was pursued. Further properties were surveyed and developed and in 1929 the railway to Alice Springs was completed.

Barclay returned to the Centre in 1911 to lead the Commonwealth Scientific Exploring Expedition which included collector and entomologist G.F. Hill. Hill made a large collection of insects and plant specimens along the route of the expedition through the Centre. The plant specimens were identified by Ewart and Davies (1917) and later published in "The Flora of the Northern Territory".

By 1930 the Simpson Desert in the south east was the only remaining unexplored area in the Centre. Madigan (1930, 1946) surveyed the desert dunes firstly from the air then later by camel caravan to complete the initial exploration and surveys of the Centre.

SCIENTIFIC SURVEYS, 1950 -

Aerial photography of the Alice Springs region was completed in 1950 and made detailed mapping of land resources in the Centre possible.

Regional mapping of land resources in Central Australia was commenced by C.S.I.R.O. in 1956 (Perry et al, 1962) at the request of the Northern Territory Administration (Perry 1967). The area surveyed covers most of the Alice Springs pastoral district and extends from the South Australian border to just south of Tennant Creek but excluding a band of country along both the West Australian and Queensland borders. The survey involved a team of scientists (geologist, geomorphologist, pedologist, pedologist, plant ecologist and an agroclimatologist) working together to map and describe the area. Air photo patterns were interpreted in the laboratory and checked by data collected from field observation sites. The final survey resulted in a map with 112 types of country which were grouped to give the 88 land systems in the final report.

Christian and Stewart (1953) defined the land system as "an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation" and these were used by the C.S.I.R.O. team as a basic inventory of the natural resources of the Centre. Each land system was described in considerable detail.

The soils of specific areas of the Centre have been surveyed by Jackson (1962), Litchfield (1969) and by the Northern Territory Administration (unpublished reports). The whole of the Centre was included in sheet 10 of the Atlas of Australian Soils (Northcote et al. 1968).

Geological survey has parallelled land resource survey in the Centre. Prospectors preceeded the explorers and cattlemen into many areas of the Centre in their search for gold, their abandoned camp-sites being the only records of their passing. In later years intensive geological surveys have been undertaken by the Bureau of Mineral Resources and mineral exploration companies. A lengthy bibliography of geological reports accompanies each geological map sheet of the Centre.

THE USE OF RESOURCE SURVEYS.

McDouall Stuart opened the route for the overland telegraph line which was completed in 1872, and a route for the movement of cattle into the Centre Rose, 1964). Cattle and sheep were supplied to the telegraph operators and linesmen at the isolated telegraph stations along the line and some of these became the nucleus herds of developing cattle stations. Other herds were brought to the Centre and by the end of 1872 the first cattle stations were being established (Duncan, 1967).

By the turn of the century, stations were being developed throughout the Centre and leases covered much of the area now used for pastoral purposes. They were extensive and not well developed. Water supplies were from springs, waterholes and a few man-made wells while cattle roamed freely over the properties.

The extension of the railway to Alice Springs and the development of stock route bores assisted the pastoral industry. Properties were sub-divided and developed but without sufficient information on the land resources. When land system mapping became available in 1962, lease boundaries were already surveyed and sub-division remained a problem, for existing lease boundaries were not suitably located.

In 1967, Condon, Newman and Cunningham of the Soil Conservation Service of New South Wales used the land systems mapped and described by C.S.I.R.O. to estimate the grazing capacity and to determine the extent of soil erosion on properties in the Centre. They assigned numerical ratings to the soils, topography, tree density, pastures, condition (as determined by erosion and weed infestation) and annual rainfall of each land system on a property and compared these with an accepted grazing capacity for the Bushy Park land system. Despite the subjectivity of the method it gave a simple numerical expression of the grazing potential of the Centre and revealed 19.2 per cent of the erodible soils in the Centre to be in poor condition.

Resource surveys are used by the Northern Territory Administration for lease rental assessment, for land use studies and for property conservation planning. Land system mapping has proved a consistent guide of property potential and has allowed a comparison between properties for rental assessment. In town planning, land unit surveys by the Administration (Sallaway, personal communication) and soil surveys by C.S.I.R.O. (Litchfield, 1969; Wright, 1958; Wright, 1959) have been used for land development in Alice Springs.

Property conservation planning developed from the need to prevent soil erosion on the extensive pastoral properties of the Centre which range in area from 400 to 3,000 square miles. The aim of the property conservation planning programme is to prevent soil erosion through the strategic location of watering points, yards and fences, and the control of stock numbers to reduce stocking intensity on erosion susceptible areas.

Property conservation planning involves both resource survey and land use planning. The land system mapping of C.S.I.R.O. was found to be too variable and to contain insufficient detail. Land unit mapping (Hooper, 1970) was accepted. The land unit remains a large tract of country in the Centre but is sufficiently homogenoeous to allow a consistent appraisal of unit capability and is an area readily recognised by the pastoralist. Condon (1968) also found that use of the land unit allowed a more precise assessment of the erodibility of each unit and more consistent assessment of grazing capacity in western New South Wales.

DISCUSSION

The vast area and the low productivity of the arid lands of the Centre are reflected in the broad scale of the C.S.I.R.O. land system survey. However, the increasing demands for land use in the Centre for the pastoral industry, for tourism, for mining and for urban development raise the problem of the intensity and form of resource survey best suited to land use planning.

The land systems of the C.S.I.R.O. survey have been derived from a range of similar types of country (Mabbutt, 1968) and are types of country rather than regional entities. For this reason it is often difficult for untrained persons not familiar with the landscape concept of land systems to make use of land system mapping. Perry (1960, 1962) reduced the land systems to eight pasture lands to allow broad generalities to be made about the potential and use of land systems with similar native pastures. However, Condon's (1968) work on the estimation of the grazing capacity of arid grazing lands and the property conservation planning work by N.T.A. indicates the necessity for a more detailed scale of resource mapping in the Centre.

The detailed land unit and component mapping by Sallaway (personal communication) in the Alice Springs town area is extremely time consuming and would only be justified for intensive development in towns, irrigation areas or for instance at Ayers Rock, a National Park with a tourist industry. In the pastoral areas such minute detail would be superfluous and could often confuse land use planning. A broad land unit appears ideal for property conservation planning in the Centre.

On this basis detailed unit mapping will be necessary on a further 500 square miles and land unit mapping for pastoral land use planning on a further 160,000 square miles in the Centre.

Land system mapping, geological mapping on 1:250,000 map sheets and RC9 photography will aid land unit mapping. Unit mapping on a regional basis would be slow and its use to the pastoral industry would be minimal until a significant part of the Centre was completed. Maximum benefit could be achieved by the selection of properties owned or managed by influential persons in the Centralian pastoral industry. Land unit mapping can then be coupled directly with land use planning for maximum benefit to the property manager and to the pastoral industry.

Throughout this paper, emphasis has been placed on resource surveys for pastoral production. Land use in the Centre is not confined to the pastoral industry. With attractions such as Ayers Rock, Mt. Olga and the gorges of the MacDonnell Ranges, the tourist industry is growing at a rate of 12 per cent a year (Anon. 1970) and has a major claim on land use. The Tourist Industry also has its land use problems. It depends on the scenic beauty of the land resources yet must provide facilities for transport, entertainment and transport in a manner which will not damage its basic attraction.

To ensure the development of all industries without conflict of interest and to ensure that the natural resources of the Centre are not wasted, attention should be placed on the use of resource surveys for land use planning and resource management. Though land unit surveys are necessary for detailed planning and management the present regional resource surveys are of a high standard and provide the basic information for regional resource planning and management in the Centre.

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THE PROBLEMS OF A WATER SUPPLY IN AUSTRALIAN ARID ZONES.

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I N D E X

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Preamble :

As the maps presented with this paper show, in terms of evaporation potential, by far the major part of Australia is arid or at least partially so. In fact with the exception of North Africa we have the largest area in the world with a run off less than 10 points per annum.

Looking at the Australian evaporation pattern compared to rainfall not just as an average, but as monthly figures and monthly averages, there is one problem we should not have in our arid zones, and that is the problem of choosing between surface and subsurface supplies. The main criterion which supports the choice of groundwater is the excessive size of surface storages necessary to cater for the high evaporative and seepage losses, and required to maintain supplies during periods of less than average rainfall.

The choice is commonly further supported by the lack of good damsites, the lack of good materials for dam construction, high siltation rates and in some cases the effect of surface storages on surrounding areas.

Few cost examples are publicized for surface water developments compared to groundwater supply systems in arid areas since the blunder is seldom made, but I have had figures quoted to me for one surface system in an 8" rainfall area where the cost would have been close to $5 million per million gallons per day if the Company had not decided against it. I might add that for this price they were assured it would not go dry more than once or twice every ten years.

Despite this, I feel some of our mining area water supplies don't stand too much close economic study, but it is always argued that these supplies were established back in history. What we must remember is that if it is a government water supply, we, you and I, pay for it and history is still being written these days when we no longer have the excuse "They didn't know any better". Thus for an evangelical groundwater supporter, arid zone water supply developments are very satisfying, though not without problems.

The problems that beset water supply planning development and management in arid areas can be broadly subdivided into four, namely :

Conceptual Problems,

Logistical Problems,

Physical, and

Engineering Problems.

Some of these problems are peculiar to Australia and our pattern of development, others are common to arid zones all over the world, and we are only just starting to learn from their experiences.

Conceptual Problems:

Australia, because of having an essentially European population in a largely non European environment, has developed in it and amongst many of its political and technical groups what can only be described as the "Australia is the driest continent on earth" syndrome. This syndrome in its worst form produces blank disbelief that any major water supplies can be developed in our arid areas. This is the first problem that planners have to overcome. I believe this syndrome is being broken down slowly to a more rational view, but part of its hold on people is due to a colossal ignorance of groundwater, its extent and its quality variations.

Let's look at a few facts. Compare say Central Australia with the Koo Wee Rup Swamp Irrigation area.

	Central Australia	Koo Wee Rup
Average Rainfall	9.5"	30"
Average Annual Evaporation	100"	40"
Rainfall reliability	Unreliable	Reliable
Rainfall periodicity	Uniform	Uniform
Surface Discharge	Nil	124 MGD

Now it is apparent that the Koo Wee Rup rainfall is approximately 3 times that of Central Australia and the evaporation somewhat less than 50%. That is, Koo Wee Rup probably has six times the water potential of an equivalent area in Central Australia.

Now the catchment area of the whole of the Koo Wee Rup Swamp is only 1320 square miles and yet the annual yield of that catchment in terms of run off and groundwater is equivalent to 132 MGD. Now in an arid area, a mining company will commonly be prepared to go 25 miles for a water supply of only 2 MGD and often further depending on the economics of the mine. This is an area of nearly 2000 square miles for a water supply which is only 1/66th of that which could be utilized in the Koo Wee Rup Basin. That is the yield requirement is less than one tenth that which hypothetically could be developed in equivalent geological areas.

There are many other examples like this, and if these were not enough, one only has to look at the far greater salinity tolerances which commonly prevail where water supplies are being developed in arid areas.

Possibly a great deal of the misunderstanding of the water supply potential of our arid zones come from a lack of basic knowledge or from preconceived notions based on old, poor or unfinished work, which has never been thoroughly analysed in terms of its real value.

We,who are working in this field, are continually regailed by what can only be described as miners tales of water supplies which inevitably include such comments as "as salt as the sea" or "an everlasting supply".

Within these tales are grains of truth, but too often they are taken as gospel. This brings me to the next problem.

Logistical Problems:

We all know that Australia's population has throughout its history been clustered around the coast and particularly around those areas of coast that had a more European or at least a wetter climate. A very small proportion of our population spend any time in our arid zones or "outback", and even fewer stay there.

The few who have lived in these areas, by modern standards have had modest water requirements, for stock, domestic, and sometimes limited areas of irrigation, if good water was easy to find. These people with time and bitter experience have learnt about the water potential of their area, but too often the knowledge has died with them. Australians have been bad at keeping and collecting records. Even now we find companies which have carried out broad exploration drilling programmes and have failed to record any water data from their bores. Estimated yield, conductivity, depth struck, water level, don't take long to record, but they can save tens of thousands of dollars in water search later if the project is successful.

Now when a major water supply is required for a mine or town or anything else they have to start from scratch. This is not true of everywhere, but away from the major areas of population or petroleum interest, it is substantially true.

Thus to the developer of water supplies in our arid zone, apart from remoteness, lack of access, an ennervating climate, he has the cost of gathering a backlog of data from existing bores and grassroots geology, before any closely direct investigation for his water supply can begin. This, plus the other problems of access etc., is one of the major reasons for the high cost of water supply development in the Australian Arid Zone.

One other problem also exists which is in part logistical and in part conceptual, and this is a problem of time. It is to me ironic that companies which spend five years exploring and testing for an ore body in an arid region expect their water supply to be located, evaluated and developed in six months.

While I have said the supplies required are commonly not large by comparison with the size of the areas looked at, to obtain the best and most economic water supply for the whole mine life and not just the most expeditious water supply, takes time and data processing in a sequential fashion. To expedite this process, involves manpower, and often wasteful surveys. Inevitably this leads to higher costs. Water supply can be a major capital and running cost in any operation and planning and investigation should be advanced in equal stages with the feasibility studies of the whole project. I am pleased to say that in the more recent arid zone projects in which my company has been involved, we have seen the latter concept being employed with much greater emphasis.

Physical Problems:

The exploration boom of the early 60's lead to the mining boom which commenced in 1966 and which is continuing to a lesser degree today. Since 1966, or more properly since 1968, calls for water supply in excess of 100 MGD have developed in the arid areas of Western Australia alone.

As I have indicated supplies of this magnitude are quite feasible in arid areas, but locating and evaluating them sufficiently reliably to base major industry and centres of population on them requires time and manpower. Further, the very nature of the boom was such that almost everybody was unprepared for it and for all the ramifications which came with it.

The physical problems of locating groundwater supplies in arid areas is much the same as locating them anywhere else, it is a matter of locating a geological environment which has large water storage capacity, is capable of transmitting the stored water to bores, and which has water stored of a quality suitable for the intended use.

Arid areas do not result directly from geology, and hence within arid areas the same range of geological rock types and environments will occur as elsewhere. These include major groundwater basins fed from remote mountain areas eg: The Great Artesian Basin, the Murray Basin, etc.

Further, aridity is a transient feature, and many areas which are now deserts, in recent geological times had more temperate climates and naturally developed the geological deposits common to such climates i.e. major alluvial filled river valleys, lake deposits, etc.

The geology that is effected in arid areas, is the superficial covering. The absence of water from the surface has a distinct effect on weathering patterns. Mineral types which in temperate and humid areas would break down and form clays, weather out as grains and pebbles;

whilst other minerals which are insoluble in cooler climates are dissolved and carried to depth in arid areas. All of these factors tend to draw a veil over the original geology, burying it beneath dune sands and cappings of various sorts.

A feature of many of these cappings is that they allow fast runoff of what little rain does occur to areas where infiltration can occur, and often at rates far higher than is common in temperate areas.

To satisfy the three requirements for establishing the presence of a viable water supply, it is necessary to understand the nature of the arid zone deposits which occur and to evaluate and understand the nature of the deposits which underlie them.

Drilling is the obvious tool for carrying out these investigations but drilling in arid areas commonly gives point information only, which is uncorrelateable to other bores. In addition where large areas have to be reconnoitred initially, and with poor access, the costs of drilling become excessive. Thus for reconnaissance work and in fact for late stage well field design, geophysical techniques are commonly used; in particular various forms of seismic refraction and electrical resistivity.

The preciseness of interpretation of these techniques depends on the understanding of the geology, especially the type and degree of cementation of the sediments occurring in the particular area, and the depth and thickness of the weathering profile on the bedrock. Herein lies another problem. Excluding much of Queensland, Australia's arid areas are also areas wherein the bedrock types are commonly Precambrian or Archaean rocks. The mineralogical nature of these rocks can be, to say the least peculiar and the weathering profile on them commonly thick and of such a nature that they are very nearly indistinguishable from the sedimentary types that occur in the same region.

Similarly, the seismic velocities of partially cemented sediments are often similar to those of the weathered mantle on bedrock. For these reasons it is essential that some test drilling must be carried out before a final interpretation of the geophysical results is made. This drilling and the interpretation of the geophysical results must be carried out by experienced hydrogeologists familiar with the area.

In arid areas where large supplies are required, it is important to establish before anything else, that a sufficient volume of a suitable geological environment is present, in which at least a few years total supply can be stored to maintain the required supply through the driest years. This apparently simple task has many problems in itself.

The calculation of storage requires a distinct delineation to be made between the bedrock and sedimentary environments and hence the identification of the weathering mantle is extremely important. No less important is the identification of the first order volume of storage in terms of specific yield for the sediments. Storage in sediments normally ranges between 10 and 40 per cent, but extractable storage is less than this ranging between 5 and 30 per cent. Where cementation is a factor or substantial clay deposits occur the extractable storage can be even lower.

The determination of storage volume in the first order, is commonly based on an informed guess, based on studies of the samples and physical measurement of the sediment volume obtained from the drilling or seismic results. In the subsequent stages of investigation, the measurements of specific yield may be made by pumping tests or at an earlier stage be estimated from geophysical logs of test bores, eg: Gamma Gamma, Neutron or S.P.

Prior to, or at the same time as the above work is proceeding estimates of recharge or replenishment rates may be made. Estimating replenishment rates of groundwater bodies is an extremely complicated matter at the best of times, but in arid areas where meteorological data is scarce, the rainfall extremely variable, and where no hydrological records exist, either surface or groundwater, little more than qualitative decisions can be made. Hence storage margins should be anything up to 10 years supply or more, depending on economic factors, and the degree of reliability which the investigator can place on his estimate.

The problem that besets the investigator in an arid area is always to assess the degree of reliability he needs to establish on these various factors before he commits either further money to investigation, or commits the company to dependence on a particular area for its supply. The decision is one based on judgement and experience. The factors which bear on the decision are the cost of the project dependent on the water supply, the cost of the water supply from any area, the variability of the rainfall, and finally the extent and reliability of his knowledge of the geology and hydrology of the area.

The other major criterion which must be considered and which is a real problem is the quality requirements of the desired water supply, in relation to the quality of the water available within economic distance of the useage point. Salinity in all groundwater provinces increases from the intake area to the discharge areas and also increases and decreases with variations in permeability. The salts dissolved in groundwater are derived initially from salts brought in with rain, "cyclic salts", and from salts released during the weathering of rocks. Thus to understand the build up of salts in groundwaters in an arid area, or in fact in any area, it is necessary to know the location of the intake and discharge areas as well as the variations in rock types in the area and their effect on salinity.

Chemical decomposition of rocks in arid areas is generally small, but certain salts are released from rocks by even the smallest amount of chemical weathering, and by mechanical weathering. In this class are calcium, magnesium, carbonate, and fluoride. In addition, typical of our Australian desert areas, nitrate, and in proximity to some geological formations, lead. The proportions of these various ions may control the use of this water.

The rate of increase in salinity away from the intake areas is largely dependant on permeability and the rate of flow. Since many of our desert areas are very flat basins of internal drainage, the rate of flow is slow. Under these conditions increases in salinity occurs both in distance and depth, and hence the storage calculated initially may have to be modified to take account of this.

From work my company has carried out in the Eastern Goldfields for instance, the following are typical of the chemical proportions of major salts in solution as percentages of the total dissolved solids.

Salinity ppm	1800 - 3000	Approx: 10,000	Approx: 100,000
Sodium plus Potassium %	23.4	24.2	32.2
Calcium %	6.6	3.9	0.8
Magnesium %	3.6	5.1	4.7
Chloride %	42.0	47.7	41.6
Bicarbonate %	11.0	2.8	20.1
Carbonate %	Nil	Nil	Nil
Sulphate %	13.4	14.5	3.5

These figures show the typical movement in chemical character towards a sodium chloride rich water. With increase in salinity this movement commences in the Eastern Goldfields at about 1800 ppm and increases rapidly initially, slowing up as the solutions become more and more concentrated.

These trends appear simple enough in themselves, but they occur in a three dimensional matrix and under the production stress move to an average salinity depending on the volume pumped, the yield pumped, and the relative permeabilities of the formations from which the water is being extracted. Thus it is difficult in fact until production actually begins, to specify the exact salinity of the water which will be pumped; though long term trends and the broad quality of the water can be predicted. If production bores of different salinity exist, blending can be used to maintain a relatively constant supply.

At least in industrial or mining requirements it is common for a broad range of salinity tolerances to be useable , frequently one portion of the supply being acceptable or even preferably saline, and the other supply of low salinity for domestic useage. Such requirements can assist in quality management and achieve an optimum useage of the waters available. Thus though the requirement of different quality waters may sometimes appear an added problem, in reality it can help alleviate the problem in the long run.

Having located the area which has the requisite storage, recharge and salinity for the project, the final physical problem of the arid zone is where to put the production bores. This is not a problem of the arid zone exclusively, nor does it have any special problems peculiar to the arid zone associated with it. For these reasons I will say no more than the location of the bores will depend on the variations in geology, hydrology and hydrochemistry determined during the programme. Where relatively uniform conditions exist, the ultimate bore spacing may simply be based on hydraulics and cost. However, more commonly it is a compromise between all the variables and both capital and running cost.

Engineering Problems:

The only remaining problems peculiar to the development of water supplies in arid areas, can be said to be engineering problems. Most of them can be overcome by the application of sound engineering practice albeit in specialized fields.

Included under this heading are:
- Drilling problems
- Soil and land subsidence
- Flash flooding
- Salinas, and
- Dunes.

Drilling of water bores in arid areas has a number of problems, some logistical others geological.

Access is commonly poor, sand can vary from sandy, to bottomless bog in very short periods of time. Rigs for initial drilling in these areas need to be light, well equipped for rough country travel, and very flexible in their operations, a combination not commonly achieved.

Initial drilling in arid areas may depend on air rotary, even though the formations are not really suited to it. Cartage of water may be impractical or unduly expensive due to access and weight.

Amongst the variety of arid deposits, are many formations which are excessively hard eg.

silcrete,
opalline silica,
ferricrete

to name but a few.

In addition, many older rock formations may have become silicified and be extremely hard. Air compressors and hammers are therefore an essential adjunct to drilling equipment for arid areas. Conversely, rocks which are commonly only slightly soluble in temperate climates, can be massively cavernous in an arid environment, and along with some of the peculiar chemical deposits, calcretes, and sponge iron, can act as lost circulation zones for everything, that can be put down a hole. Where such formations form below water table, they are major yielding zones, but they can be difficult to develop, because of their hardness, yield when air drilling, and cavernous nature.

Possibly the most frustrating formation for the drilling contractor are the chemically active clays and evaporite deposits. Too soft to be drilled with air, they flocculate bentonitic drilling muds. With the aid of a mud engineer on site, it is possible to overcome these effects. Percussion rigs are another answer, but they generally lack the speed of operation desired.

Land Subsidence : is a problem which may occur in any area of groundwater development, but is commonly more serious in arid zones due to the greater fluctuation in water levels which occur as a result of variations in recharge, or simple mining of water. It is particularly a problem of areas where the yielding aquifers are confined, and results from the removal or depressurization of water which has in fact been part of the lithostatic support elements. Within the sediments in its simplest form it can occur progressively with the dewatering or depressurization of the aquifers; or in its worst form it can occur suddenly due to a resorting or rearrangement of sediment packing geometry. The latter situation has a higher probability in arid areas or where sediments have been deposited under arid conditions, because cubic open pack grain arrangements are more commonly developed in this environment.

No positively identified cases of subsidence have been documented in Australia, but many examples exist overseas. The effects are to produce a depression over the area of most concentrated pumpage and in the worst cases can cause disruption or serious damage to surface installations, eg: pipeline, rail and roadways, towns, drains, etc.

Finally flash flooding, the problems of dunes and salt lakes all affect the development of water supplies in arid regions. The extent of the problem they cause depends on the money available for developing water supply points. They represent either danger or obstacles to access and the construction of pipelines, and thus to a greater or lesser extent they may control the areas that can be developed as supply points.

Conclusion :

These then are the problems of developing water supplies in the Australian arid zones, and they are challenging problems in every job, for the planners and developers to overcome.

In almost every case the problems can be overcome by greater expenditure in investigation and development phases. Presently costs of water supplies up to the point of supply at the surface range in cost between $20,000 and $170,000 per million gallons per day; the variation reflecting the variations in the problems encountered, Whilst the upper limit is high by comparison with temperate zone groundwater supply costs, the actual investigation costs are always justified by the savings in pipeline cost achieved in a thorough investigation. The following examples illustrate this :

Area	Supply MGD	Anticipated Pipeline Miles	Eventual Pipeline Miles	Investigation Cost $
Pilbara	3	60	25	250,000
Pilbara	2	18	5	160,000
E. Goldfields	2	200	30	300,000
Central Australia	5	250	60	300,000
N.T.	6	24	11	80,000

The examples I believe demonstrate the necessity for detailed investigations. The problems to be overcome in the arid zone are challenging, what then of the change?.

In the future we will see change, in many areas simply due to the experiences and data being collated and collected now. However, with growing demand already certain problems have arisen, particularly as to whether mining of groundwater resources should be permitted. The arguments for and against this concept are many and complex and I shall not go into them here. My own opinion is that :

(i) mining of water is not a permanent situation and if the economic return warrants it then, water should be allowed to be mined.

(ii) the rate of mining of water can be minimized by properly designed water harvesting and artificial recharge schemes, and

(iii) to claim that the water is being protected for future generations is simply a matter of putting off the decision.

Australia has a long way to go in the establishment of rational and viable water development policies and nowhere is this more true than in our arid zones. Organisations such as the W.R.F.A. and the groundwater body, the National Water Well Association of Australia must strive towards gaining reasonable policies on conservation, and non pollution of water supplies wherever they may exist and particularly in Arid Australia.

Finally in the future we can expect to see reductions in the costs of water supply investigation as a result of -

(i) the use of earth orbital multispectral imagery, and

(ii) the benefits to be derived from nuclear fracturing, and other advances in yield optimization from bores, and

(iii) greater government expenditure on our arid zones which have suddenly become of interest to our nations welfare.

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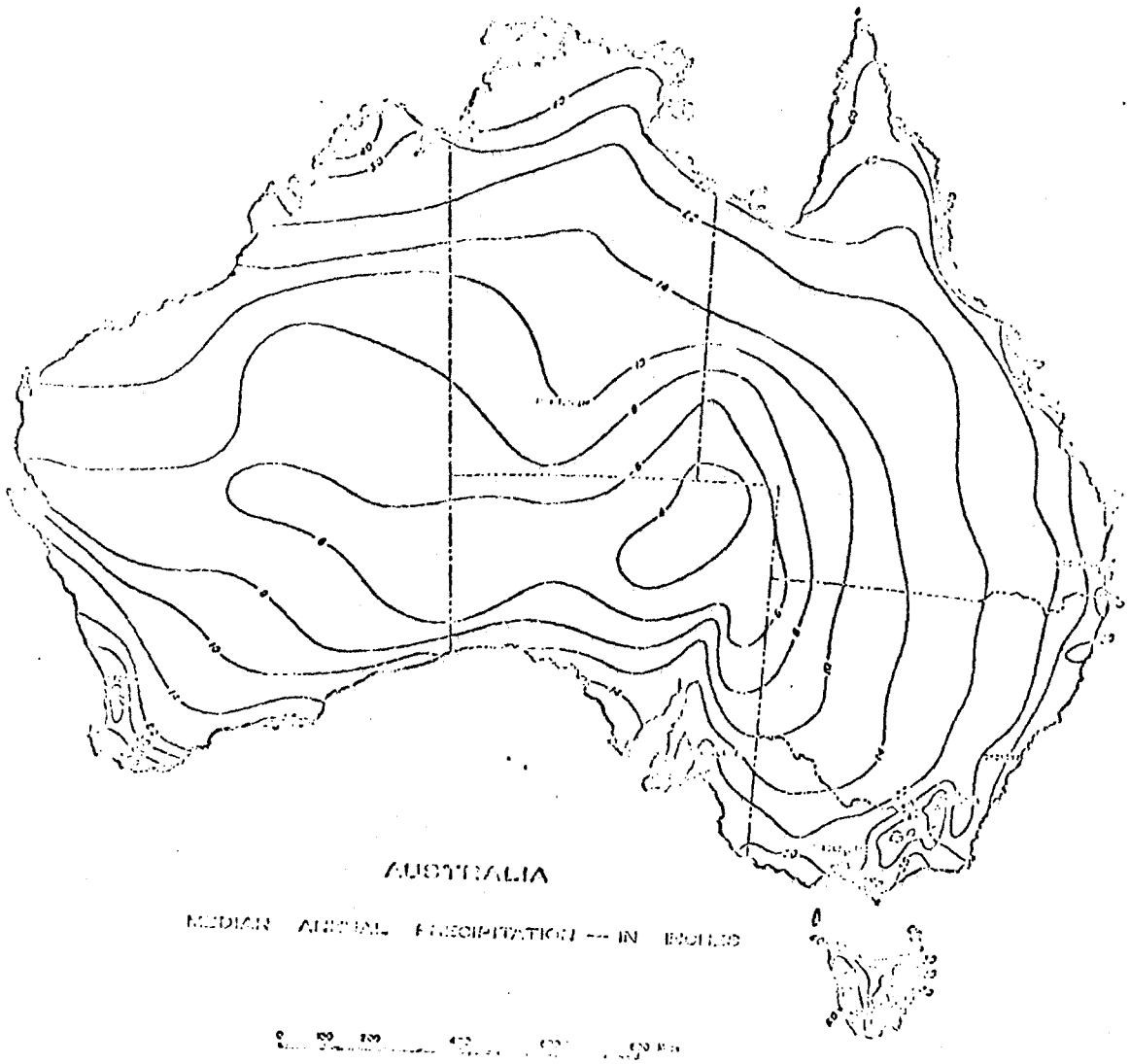
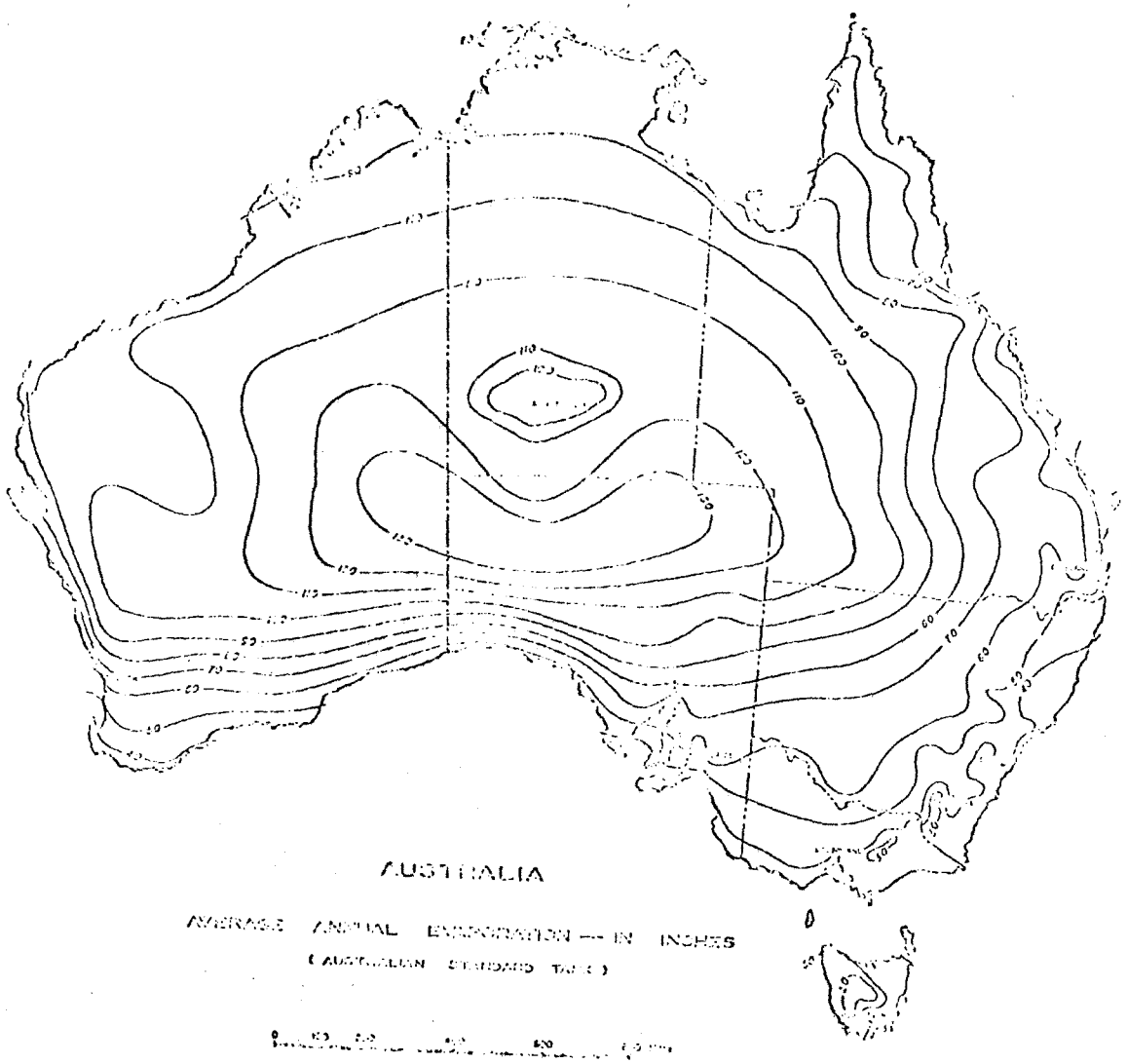


AUSTRALIA

MEDIAN ANNUAL PRECIPITATION — IN INCHES

by



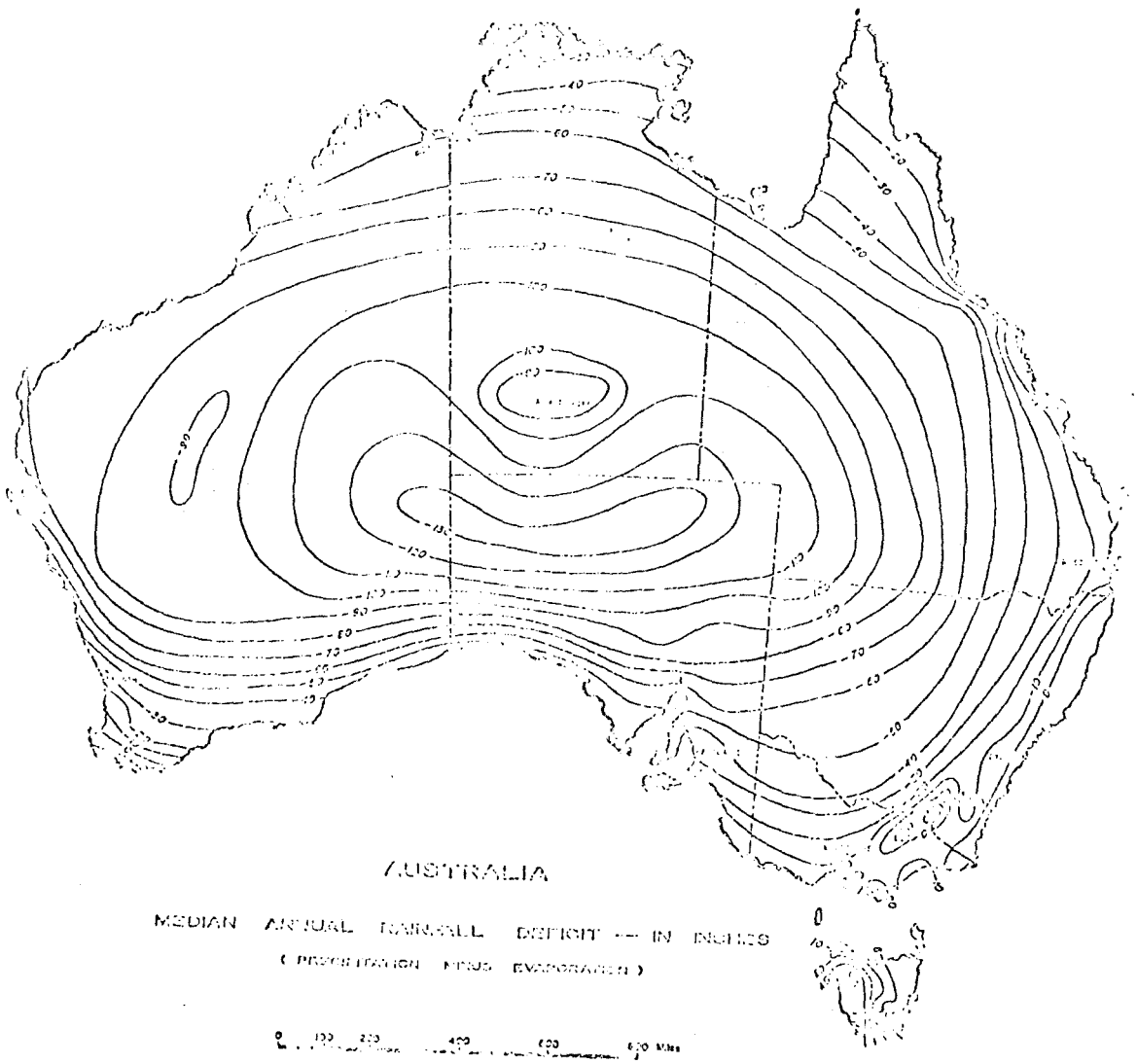
AUSTRALIA

AVERAGE ANNUAL EVAPORATION — IN INCHES

(AUSTRALIAN STANDARD TANK)

by

Australian Groundwater Consultants Pty. Ltd.



AUSTRALIA

MEDIAN ANNUAL RAINFALL DEFICIT — IN INCHES

(PRECIPITATION MINUS EVAPORATION)

0 100 200 400 600 670 Miles

by

Australian Commonwealth Commission Pty. Ltd.

A TOWN LIKE WINDARRA

H. B. Young

Kinnaird Hill deRohan & Young Pty. Ltd.

INTRODUCTION

There are many problems facing those who are fortunate (or perhaps unfortunate) enough to have the job of developing a mine in a remote area of Australia. Finance, mining method, type of concentrator, transportation, power supply, water supply and accommodation of the workforce are all matters which readily spring to mind when initially confronted with such a problem.

One factor which can be easily under-rated in importance and yet which can perhaps contribute much to the success and smooth running of the mining operation is accommodation for the workforce. Establishing an operation of any size in the remote areas of Australia demands the provision of adequate accommodation not only for the construction workers but eventually for the production workers also.

This latter case usually requires a township to be established and I would like to talk today about the way one company, Poseidon Limited, is tackling this particular problem.

The Mount Windarra mine is located approximately 60 miles north east of Malcolm, the rail head 170 miles north of Kalgoorlie.

The Windarra region is isolated, it has a harsh climate, water is scarce, the land form is generally uninteresting and vegetation is sparse and of poor quality. Naturally, it is poorly endowed as a place for human settlement as are nearly all other places within hundreds of miles of it.

These conditions impose many restraints on the planner that are not normally confronted in a less hostile environment. The township of Windarra will differ markedly from what can be considered to be the normal remote area mining town and it will be interesting to see how it fairs in the future by comparison.

SITE

The site chosen is located approximately 7 miles south west of Mount Windarra on a series of sand ridges elevated 25 feet to 85 feet above a salt lake system which parallels Windarra Range 2 to 3 miles to the west. The ridges generally run east-west and are moderately steep towards their tops. The soil is a fine red-brown sand to depths of about 15 feet and the higher ground has sufficient elevation to offer quite extensive views to the Windarra Range. Vegetation is not thick, spinifex is the only ground cover, but there is a sprinkling of mature eucalyptus up to 30 feet in height. In comparison to the surrounding country, this site offers much towards an interesting and effecive town development.

POPULATION CHARACTERISTICS

Before any real planning can proceed, an assessment must be made of the size and type of population. The population of a mining town is of course a function of the manpower required for the mine and process plant, but it will be appreciated that many other assumptions must be made in order to arrive at a total population.

Starting with the manpower as a base, it is possible to build up figures, based upon experience in other mining towns, for married and single population, consequential population (i.e. not employed by the company) numbers of children and the likely changes in the form of the population during the life of the town.

For Windarra, planning proceeded on the basis of a growth to a total population of approximately 3,500 which included a workforce of 1,280, 820 wives, 1,390 children and 650 pupils.

The assumed build-up of the total population and workforce is shown on graphs 1 and 2.

CONCEPT

From the outset it was recognised that Windarra must overcome the problems of isolation and remoteness in a harsh, dry, arid climate. Mining is hard work made more so at Windarra by the climate. Compensation for hard work in harsh conditions can be in part in cash, but in part it has to be in comfort and interest outside the mine, not only for the miner but also for his dependents. For the company to be able to attract and hold an adequate workforce in this area, not only must the wages and working conditions be competitive, but the township must provide an attractive environment for the men and their families to live in.

To achieve the necessary oasis environment in an area where, to say the least, water is not plentiful, it was necessary to consider higher densities of population in order that the total area of the town could be reduced. A reduction in town area achieves a reduction in service costs such as roads, water supply, sewerage, etc., and consequently allows a correspondingly higher sum to be spent on improving the quality of the dwellings.

Accordingly, the accommodation that will be provided at Windarra will be somewhat different from that normally encountered in an Australian town. Lot sizes are considerably reduced to minimise maintenance. Many of the houses are of the courtyard type, gathered together in small groups separated from each other by areas of common reserve, which will be maintained by the town commission. Two storey apartment blocks and town houses will be grouped around the town centre

and single men will be housed in apartment blocks with common messing facilities rather than in the barrack type apartments so common to mining operations of the past.

The concept of the town, and in particular the higher density housing development, will rely heavily on the success of the landscaping of the green reserves. The utility of these areas, their appearance and ability to be easily maintained in the climate without the extravagant use of water, is of the utmost importance. The existing large trees and shrubs will all be maintained and supplemented by new plantings of species suited to the soil conditions and the climate.

TOWN FORM

The shape of a town is conditioned by many factors, but for a community of 3,500, the most efficient form of development is a town centre comprising all commercial and community facilities, surrounded equi-distantly by a ring of housing with radial traffic ways and a perimeter road matching desired traffic movements.

Topography at Windarra discriminates against the hypothetical form and therefore, a more lineal development has been adopted flanking ridges to improve the aspect and make the most of ground fall for drainage purposes. The complication of multiple catchments, further restricts town form in order to reduce sewer and drainage costs. Additional restrictions are imposed by adjoining mineral leases and by a 7 mile zone around any future smelter which must be kept free of human settlement. These basic factors dictated that the town must have a multilineal form along ridges in the same catchment with the town centre, in a position where it can have the greatest visual impact but at the same time be located centrally to the maximum number of people.

TOWN SYSTEMS

RESIDENTIAL

A range of housing types will be provided because of the variations in the marital status of the workforce, family size, income level and nature of employment. The bulk of the residential accommodation will be family dwelling units arranged in cohesive groupings which are separated by informal space and linked to the town centre by footways.

Apartment buildings for married couples without children or with one child and town houses for families preferring the advantages of higher density accommodation, will be located near the town centre to give it more emphasis.

Accommodation for single men will be near the town centre and close to central messing and recreational facilities. This accommodation will be broken down into smaller groups of buildings rather than one large complex.

COMMERCIAL

Windarra will be a small isolated community and nothing will influence its success and integrity more than the visual and functional size of the town centre.

It will be overwhelmingly commercial in function with shops, licensed premises and storage buildings occupying the greatest areas.

The most heavily trafficked shopping areas will be located to avoid a hot easterly wind in the summer time and provision will be made for continuous summer time shade.

Parking areas will be small spaces rather than vast expanses of unbroken bitumen and will be so arranged that they can be used day and night by people using different facilities.

RECREATION AND LANDSCAPING

The importance of an interesting, useful and appropriately landscaped recreation system at Windarra cannot be overemphasized. Because of its isolation and the scarcity of natural attractions in the district, leisure time will be spent in the town and there must be ample recreational activities for the residents. Basic recreational facilities will be provided in initial stages of town development and grouped to get maximum economy in maintenance and landscaping, in the use of change rooms, equipment and parking areas. The recreational element will be central to residential development and linked through to housing areas by informal space and footways.

Informal open space will occupy more area than any other land use except housing. It will function as a buffer between buildings and other use areas, as a landscaped screen between houses, as a backdrop to buildings and as a play area for children. As far as possible, it will be continuous, easily and cheaply maintained and combined with a pedestrian circulation system which will encourage people to use and walk through it.

TRAFFIC

Road safety must over-ride all other factors in the design of a traffic system for the town. Road and footpaths will be developed so that conflict between people and vehicles does not occur.

To do this, two aspects must be kept in mind. Firstly, people will prefer to drive rather than walk, so that most of the adult and family journeys within the town will be by car; secondly, pathways must adhere as closely as possible to pedestrian desire lines. In other words, a convenient road system should not be sacrificed to a pedestrian system which is complete in its operation unless there is a predictable pattern of heavy pedestrian use. This implies that pathways should be short, e.g. a walk of a third of a mile from home to the shops is probably the practical limit in the summer climate with somewhat longer walks from home to school, but in any case, they should be shorter than the alternative road route.

The pedestrian pathways will be easy to walk along, i.e. have easy grades, and they will be lit at night, to impress as safe places not back alleys to run through or avoid.

From the safety point of view, attention will be given to the road system. In theory, a main perimeter road is considered to be the best method of circulation in terms of safe and fast traffic distribution. Intersections occur only on one side except at the intersection of external roads and so the number of conflict points is reduced and the pattern of movement becomes more predictable.

SOCIOLOGY

The most important objective in formulating the town design was to ensure that the physical development would maintain, to a maximum degree, a stable and contractual workforce at Windarra. An examination of the sociological population, and economic characteristics of the future Windarra population was necessary before planning to secure this objective.

MARITAL STATUS

The anticipated marital status of the workforce at Windarra has already been given. Comparison of these statistics with Western Australian averages shows that, at maturity, the Windarra population will be relatively balanced with, if anything, a slightly higher percentage of married people in the community than is normal. Obviously, in the early years and until the stage is reached where 70% of the workforce is married, the composition will be abnormal, with a large number of single people in the town. This feature of population make-up is common to most mining towns and, in northwest Western Australia, no mining community has yet achieved a workforce married component of more than 65%. However, with the exception of one mine with short life, all are striving to attain more married men because of their far greater job stability. At Windarra, where the mining operations will be an underground one compared with open cut in other areas, it is anticipated that the workforce will tend towards a higher percentage of married personnel.

AGE GROUPING

In general terms Windarra will have a highly pronounced young population. A high proportion of the population will be children under 15 years of age with only a few middle aged and elderly people. The age grouping is going to be unnatural and had to be planned for accordingly. Without grandparents or other elderly folk to look after children, motherhood will be constant for wives unless adequate child care centres are available. As working mothers will be depended upon to a large extent for full and part time labour in the town, it was essential to provide child care/kindergarten centres for pre-school education and necessary care of the children. These facilities have been located centrally in relation to the family housing groups and provided with pedestrian paths and one avenue of vehicular access.

Because of the youth of the population there will be high rates of community participation in active sports which will be further emphasized by the introversion of leisure time activities. Activity rates in recreation are likely to be matched in civic community pursuits.

As the people will be young and virile, the birth rate must be expected to be higher than normal. Facilities in excess of standard provisions in balanced communities for all these aspects will be provided in the town to maintain community content and stability.

SEX

There will be a large male percentage in the population at Windarra at all times with a comparatively small percentage of females in the 15 - 45 age group. This imbalance will be greatest at the start of the project when the company workforce will be 70% single men. In the first year of Stage 1 operation, single females are likely to be outnumbered by about 40 : 1. As the town matures, the female/male balance will improve but never to the point of equilibrium.

To minimise potential trouble from this source, the single workforce will be phased out as quickly as possible. In the physical planning of the town, attention has been paid to encouraging better behavioural standards by providing decent and dignified accommodation. The accommodation is utilitarian and designed for constantly changing tenancies. In this sense, we have departed from dormitory type accommodation in favour of flats or small group accommodation with single room occupancy. The single men's quarters will not appear to be for second class citizens nor will they be visually isolated, but there will be some separation from family accommodation.

ABORIGINAL POPULATION

The mining operation at Windarra will experience unusual problems for Western Australian mining towns because of the relatively large native population which is centred at Laverton, 14 miles away. A specialist opinion on the native population in the Windarra district and the interaction of this population with the new community at Windarra was sought from two specialists well recognised in the fields of aboriginal antropology and sociology.

Both these experts contended that Laverton should remain as a native centre in the interests of both the aboriginal and European populations. They contended that provision for housing natives in Windarra should only be made for those natives actually employed by the company or by the consequential workforce. Natives so employed will have similar accommodation to European counterparts and we believe that, with training, which could be sponsored by the Native Welfare Department, a percentage of the native population can be expected to be reliable and able workers for the company.

COMPARATIVE INCOME

The relative earning opportunities at Windarra compared with competing mining ventures in other parts of Western Australia will have sociological significance in that it will affect the stability of the workforce. Unlike most of the new mines of the northwest, Windarra is an underground operation with consequent restrictions on the duration and frequency of shifts that can be worked. In addition, the mine is located outside the primary income tax concession zone. As an underground operation, there is likely to be some psychological reluctance to work at Windarra compared with the open cut mines. Coupled with the relative isolation and unattractive surrounding countryside, the town will not fare well in a hypothetical labour market unless compensation by way of incentive payments is achieved and the town offers better-than-normal living conditions to the broad range of the workforce. Hence the accent on providing better standard accommodation.

LEISURE TIME

Leisure time has been referred to previously. With the particular type of mining operation at Windarra, workers are going to have comparatively more time off the job than the majority of so-called miners in the northwest. For this reason, strenuous efforts will be made to organise community and recreation facilities and we will probably see the employment of a recreation officer for the town.

Mining communities are renowned for their drinking prowess. Circumstances at Windarra could make the locals champions. A good quality hotel will, therefore, be provided at an early stage. The hotel will be the social centre for the single workforce and very largely the entertainment centre for the community and as such it will be designed to function accordingly.

LANDSCAPE

The concept of town development recommended for Windarra relies heavily on the success of the landscaping system, its utility, its appearance and its ability to be easily maintained in the hot and dry climate without extravagant use of water. The existing large trees and shrubs will have to be retained wherever possible and supplemented by new plantings of species suited to the soil conditions and climate and to the use which will be made of the various spaces.

The town will be classified into 4 planting zones :-

Zone 1 : Areas which require 2 inches of water per week. Plantings will be lawn, massed shrubs and large shade trees.

Zone 11 : Areas which require 1 inch of water per week. These will include lawn areas, the main recreation area and oval, play areas and pedestrian spaces.

Zone 111 : Areas which require 1 inch of water per month. These will be improved bush areas with plantings of additional trees and shrubs and will include road verges, end spaces of paths, and outer spaces around single men's quarters, flats, town houses and the central recreation area.

Zone IV : Areas not requiring additional care except during the establishment period. These areas will be planted with additional trees and ground cover and will be mulched.

Contractors will be restricted to movements of vehicles on roadways except for services which have to be laid in pedestrian ways. In fact, during the construction period, it will be specified that any contractor destroying a tree will be penalized $100.

Before locating buildings in plan, a special walkover survey of the site was carried out and every tree has been located and marked on all site drawings. In this way, the removal of trees has been kept to a minimum and to date we have had very few trees damaged by contractors.

The root systems of large trees are, of course, delicate and so too close excavation was avoided wherever possible. Planting and paving will commence progressively as the contractors move out and each section of the pathway system will be planted as the housing is completed.

It is proposed to surround the town and the adjacent landscaped area with a fence. The area within the fence will be proclaimed a reserve. It is hoped the fence will achieve two main objectives. First it will keep stock and native animals out of the area and so give the native vegetation a chance to grow unhindered by grazing and secondly it may be successful in preventing the aborigines from cutting down all the trees for firewood. It will be interesting to see how effective it is.

WATER SUPPLY

It is expected from development work to date that suitable supplies of potable water will be located within 20 miles of the town. All the investigations have been carried out to date by Mr. Hancock's firm, Australian Ground Water Consultants.

Water consumption in mining towns in Western Australia vary considerably according to climate, water quality, water costs and town design. The domestic usage which is considered adequate for Windarra is a peak supply of 200 gallons per head per day with a yearly average of 90 gallons per head per day.

The reduction of water demands for other uses will be made by planning for the use of sewage effluent for irrigation of sports fields and dust suppression. The irrigation demand for planted areas is estimated at 200,000 gallons per day for Stage 1 of which approximately 25% would be supplied by effluent.

WATER QUALITY

Records of water quality to date indicate that some water treatment will be necessary in the form of desalination and softening. The extent of treatment and the methods of treatment are still being evaluated at this stage.

IRRIGATION

As indicated, the Stage 1 requirements for irrigation will be approximately 200,000 gallons per day. Where possible irrigation pipework will be installed from the outset to provide a permanent sprinkler system. Areas between housing clusters will be provided with sprinklers from the water supply mains.

It is planned to use trickle irrigation methods where possible, but problems of vandalism are yet to be overcome and the Western Australian Government has regulations prohibiting dripping taps which may yet prove difficult to overcome.

SUMMARY

In the time available, I have tried to give as complete a picture as possible of the thinking which has gone into the planning for the town of Windarra. Obviously, I have not been able to cover all aspects but I have attempted to cover those areas which are particularly affected by the location of the town and its environs.

The planning and design of the town were undertaken by a multi-disciplinary team which we assembled for the purpose. It included Hassell & Partners, Architects, T. S. Martin & Associates, Town Planners, Professor Dexter Dunphy (Professor of Business Administration and Head of the Department of Behavioural Science) and Mr. G. W. Ford (Senior Lecturer and Head of the Department of Industrial Relations, School of Economics), both from the University of New South Wales. Special assistance on landscaping was provided by Mrs. J.Verscheur. This team functioned extremely well and the interplay of ideas between specialists from all the disciplines required for the town achieved practical and economic solutions to many of the problems which we faced.

There is a challenge to designing a completely new town in the arid lands of Australia and I believe these challenges have forced us to adopt a different approach to town planning. At this stage, I think I would like to live in Windarra. I hope the mining population will also.

MINERAL RESOURCES AND ARID LAND DEVELOPMENT

L. W. Parkin

Director,
Australian Mineral Foundation

Excluding coal, the great majority of Australia's presently known resources of minerals are located in arid portions of the Continent. Some of the reasons for this are self evident and others more subtle, most of the continent is arid anyway and aridity tends to slow down the forces of leaching and removal of near surface evidence so that many prospecting methods work more effectively in arid areas and discoveries are more frequent. Some of the minerals being won, owe their presence in economic form to cyclic aridity e.g. the lateritic nickel and bauxite, and probably the iron ores of the Hamersley area.

Geologically, the Australian continent comprises a generally stable ancient shield with instability and therefore younger rocks increasing towards the east. In general the easterly mountain ranges are younger and less mineralised and the final blanket of mesozoic and younger rocks, not generally mineralised at all. Hence we find most of our base metals in the central and western portion of the Continent, where we also of course find most of our arid lands. These sort of generalisations always arouse argument because exceptions keep coming to mind, but they are basically applicable.

The mineral resources of the less stable, less arid eastern highlands are mostly either small, or are related to volcanic activity and generally are less persistent. Hence in this country mineral resources and aridity seem to belong together.

Fortunately the winning of minerals is the least damaging ecologically and environmentally of all forms of occupation, especially in arid lands. In fact the winning of minerals is an ideal form of arid land development for the following reasons:

1. It is very local in it's occupation of land. Unlike pastoral activity, which tends to upset the ecological balance over thousands of square miles, the winning of minerals is limited to a few acres so far as the mine is concerned and a few tens of square miles to contain the community.

2. In arid environments it is necessary for the project to take great care, to ensure attractive living conditions in order to maintain a reasonably stable community. This inevitably means the development of a local water supply, the planting of trees, the prevention of local soil erosion, the elimination of dust.

3. The productivity of mining in terms of return in relation to man-power, is relatively high. The value of annual output per employee averages $22,000 compared with $9,000 for a rural worker and per capita export value is $16,000 as against $4,000 for a rural worker.

In the early days of settlement of the Australian Continent, there was no attempt made by any of the colonists to come to terms with the arid environment. It was inhospitable and life was so harsh that any concern for the preservation of natural phenomena, fauna, vegetation or natural beauty was the exception. Hence the agricultural, pastoral, mining and community messes of that period. To some extent time has healed many of these ancient scars - the derilict farms of the marginal lands, the abandoned stations, the old mining camps - have an historical aura about them which bestows a certain sanctity. Their like will not be tolerated again. The mining industry acknowledges this somewhat irresponsible attitude of its predecessors and pleads that bad as some of them were, they were neither better nor worse than the standards of the community at that time.

The change in attitude of the mining industry commenced long before environmental concerns became a popular community movement. This is understandable in that miners live in remote places and develop a sense of belonging there. They take pride in their association with the bush. Field naturalists movements thrive and a general interest in their surroundings is the norm. Hence it was in the 1930's some forty years ago that to my knowledge the first serious large scale attempt was made in Australia to arrest arid land deterioration and to restore some of the damage of human occupation. I refer to the work in Broken Hill undertaken by the Companies, designed and carried out under the guidance of the late Albert Morris. The regeneration zone around the city has staged a remarkable recovery in this time and of course the additional beautification and water conservation schemes have converted the Broken Hill area, into one which would astonish the early explorers of that dry and inhospitable region.

The Broken Hill pattern has now become the normal design for mining fields throughout the Australian arid regions. At Mt. Isa there are now four artificially impounded inland lakes in an area which was previously practically devoid of surface water.

* Extract from Sir George Fisher's paper - "Mining and the Environment - The Mining Industry's Responsibility".
"As a result, the birdlife in the area has increased tremendously - these four reservoirs have a total surface area of more than twenty square miles and are sanctuaries. In the drier period of the year wild duck and other water birds flock to these reservoirs in their thousands - on some occasions the wild duck population of Lake Moondarra at Mount Isa has been estimated at over 100,000. As a result of the establishment of these lakes by mining companies, North West Queensland now has secure habitat for wild duck and other birdlife which would either perish or have to leave the area in drier times."

A similar situation can be described in other inland mining towns such as Cobar, Kalgoorlie, Weipa, Mary Kathleen and many others.

In South Australia one can consider Whyalla and Leigh Creek in this category of an acceptable even desirable, arid land mineral development.

In both cases a strenuous and effective effort has been made to minimise environmental damage and to offset unavoidable damage by regeneration or other control programmes. The introduction of water supplies into an arid area is of itself a major offset to some of the other disabilities of human occupation, the effect on bird life is dramatic.

A carefully planned mining operation in an arid area can be wholly acceptable from all points of view. I regard Leigh Creek as a model in this respect. The township is an oasis on what was previously a desolate treeless plain. The open cuts, while not beautiful, have some topographic interest and replace what nature had left as saline gypseous badlands, devoid of vegetation and interesting neither to man, bird nor beast. The water catchment scheme is a haven for every inland species of bird life.

Much of arid inland Australia is underlain by the waters of the Great Artesian Basin. This water has permitted acceptable pastoral development in areas where there is sufficient natural precipitation to maintain stock feed, but has also enticed such development into areas where feed is either inadequate, or so delicately balanced that the introduction of stock has prevented any regeneration. Much of our inland desert is of course pastorally induced in this way. It happens however that some of the Great Artesian Basin country contains in addition to water, significant supplies of fossil energy-oil and natural gas. The exploration programmes which are necessary to locate these resources, involve short term intensive activity - the running of seismic traverses, the drilling of wells - and passing on. Twelve months after an exploration programme is over, the surface evidence of the work is hardly visible. Of course there are the usual human problems of careless contractors, litter, and the control difficulties which arise from remote communications, but in general, petroleum exploration is undertaken with a sense of responsibility and the need to minimise surface damage. Where discoveries are made, permanent production facilities are established and necessarily some forms of community centre must be supported. In the case of a petroleum project this involves a relatively small number of people, but as with a mining centre, it necessitates a water supply and with it the opportunity of regeneration in the desert, and the development of a sanctuary for bird life.

These features are already becoming evident in the Moomba area where the natural gas plant has been established.

As with mining the production of petroleum is an acceptable form of development in arid zones, with few if any permanent ill effects. This contrasts with the hazards of pastoral occupation.

I have not so far mentioned the very obvious role of mineral development in decentralisation of population. There is a great deal of talking of the need to discourage the overgrowth of cities, of the adverse environmental effects of urban land development, of the air and water pollution problems aggravated by large centres of population; but very little positive thought is given to the only alternative, which is the development of industries in rural or arid areas. I suspect that this alternative is regarded by some, as even less desirable than urban concentration, but I would suggest that this is not a proper position to adopt.

The Mining industry offers one of the few opportunities for decentralisation now that the agricultural and pastoral industries have reached, what appears to be, saturation point. In fact so far as South Australia is concerned and the same applies in varying degrees in other states, the original impetus to development away from the coast was provided by mining - I refer to the early mining centres of Wallaroo, Moonta, Kapunda, Blinman and the now revived centre of Burra. In addition there were dozens of other towns which flourished for a short while before settling back as agricultural centres. Throughout Australia, there are many other obvious examples, some of which have remained inland cities long after the mining interests have wained, e.g. Ballarat and Bendigo.

During the last decade, a large number of arid land mining ventures have come into production. The Australian Mining Industry Council last year conducted a survey of eleven of the major ones, all of which are located in areas which had hitherto been virtually uninhabited - (* Extract from - A.M.I.C. Survey of Infrastructure Costs). "Total expenditure by the companies concerned during the period was $800 million, of which $515 million was spent on "infrastructure" and only $285 million on production and handling facilities. That is, for every million spent on mine development an additional $1.81 was spent on infrastructure, thereby almost trebling capital costs.

The following table shows the break-up of this expenditure :-

Infrastructure Costs	$ million
Ports	125
Railways and other product transport	200
Town construction	93
Utilities (power, water, etc.)	73
Off-mine roads	13
Grants to local authorities	9
Airstrips	2
Total	515
Mine Development	285
Total Project Cost	800

Eight new ports had been constructed involving the dredging of approach channels, the provision of navigational aids, construction of wharves and loading facilities and the provision of tugs and general port services.

Five hundred miles of railway lines had been laid, together with the provision of earthworks, bridges, culverts all rolling stock and extensive workshops.

Thirteen new towns had been built with populations ranging from about 250 to over 3,000, and averaging about 1,000. Included in the town expenditure was the cost of providing shopping centres, schools, hospitals, churches, amusement and recreation centres and sometimes even jails.

All of the projects involved the provision of power and water supplies and other local amenities.

Seven television stations had been built and two translators installed to extend to mining towns already existing services.

Seven airports had been constructed, ranging from small strips for light aircraft to fully paved runways to cater for jet aircraft on scheduled airline services.

I will conclude by referring to a growing tendency to deplore and to inveigh against all forms of development, no matter what precautions may be taken by way of preliminary environmental studies and subsequent controls. In fact there is a prevalent school of thought which takes the view, that an environmental study which

does not recommend against a proposed development is therefore an inadequate study. This attitude is both impossible and depressing as well as being hopelessly self-centred. Whether we like it or not, our population will grow and our children are entitled to the same opportunities for a satisfying life, of ever improving quality, as we ourselves enjoy.

This brings me back to the opportunity for decentralised growth which mining projects in remote areas offers.

May I share with you an un-nerving sequence which I recently experienced in this regard. Some months ago a preliminary copy of a proposed development plan for the Flinders Ranges prepared by the Planning Department was obtained by the press and published. The plan showed that all of the core of the ranges comprising some 1,100 sq. miles was to be declared "Class A" i.e., to be exempt from all forms of occupation. This was surrounded by a "Class B" zone, for limited pastoral pursuits only.

Although the Flinders Ranges have always been of great mineral potential, and currently are the focal point of an annual $5 million exploration effort, the above classification is proposed. Notwithstanding detailed prior submissions made by the Department of Mines no provision whatever was made for mineral development. Following the publication of the plan, the Department of Mines prepared a counter proposal, which left as "Class A", 90% of the area shown in the plan, added to it another 700 sq. miles of magnificent scenic country which the plan had omitted, but urged that certain areas of already known great mineral value be deleted from "Class A" - recommending none the less, that any mineral development in this areas be under strict controls and requirements in respect of environmental damage. What we were urging was the opportunity for the development of one or two new township centres, adjacent to the ranges such as Leigh Creek, with a controlled mining operation in the ranges nearby.

This we regard as an opportunity for decentralised growth, a water conservation project, tourist centre etc. The case was developed, and presented to the Planning Authority. However, it was rejected - except that I understand that the expanded "Class A", proposed in the submission is now to be included. When this plan is finally published for public comment, I hope the public response is loud and clear.

By all means let us preserve the beauty of the ranges, let us prevent despoilation by roads, litter, etc.. But do not condemn all of us to live in cities, so that a few lucky ones can occasionally get themselves several hundred miles from the nearest settlement. Among rational people, there is room for compromise and I submit that the occasional, rare, valuable mineral deposit which leaves 99.8% of our undeveloped country still undeveloped, is a compromise worth making.

CONSERVATION AND UTILISATION OF NATURAL RESOURCES IN THE ARID ZONE OF THE USSR

Dr. N. N. Drozdov

The arid territories, or deserts as we call them, occupy an area of about 210 million ha, or 9% of the total area of the USSR. They are found mainly in Central Asia and southern Kazakhstan, from the eastern shores of the Caspian Sea in the west to Tjan Shan and the Pamir Mountains in the east, from 48°N to the Kopet-Dag Mountains in the south. A brief look at the geological history of this territory shows that already in early Tertiery times the Turgay Tableland was above sea level. To the south there was a South Asian sea. In the Oligocene period the level of this sea dropped exposing new land. In the Quaternary period, the Amu-Dar'ya and Syr-Dar'ya Rivers constantly changed their course through the lowlands. The Amu-Dar'ya flowed into the Caspian Sea and the Tejan and Murgab Rivers were its tributaries (Fig. 1). In the second part of the Quaternary period the Amu-Dar'ya broke through the northern part of the Karakum region and flowed into the Aral Sea (Fig. 2).

The main types of deserts are the stone desert with sparse xeromorphic vegetation; the sand desert with shrubs of psammophyte vegetation; and the salt mud desert with sparse galophyl vegetation.

The climate in our deserts is a very continental one, with significant differences between northern and southern deserts. Northern deserts are of the Mongolian type and southern deserts are closely related to the deserts of Asia Minor.

In the northern deserts the annual rainfall of about 160 mm is uniformly distributed throughout the year. Temperatures in January drop to -42° C (average -15°C) and the July average temperature is +28°C. The amplitude of temperature variation within a year is about 75-80°C (Fig. 3A).

In the southern deserts the annual rainfall is about 110-120 mm with concentration of rainfall in winter and early spring. In the summer period some two-three months receive no rainfall. The average temperature in July is 32°C (maximum 50°C) and the January average temperature is 2°C, (minimum -29°C) (Fg. 3B). Such a large variation in winter is explained by the intrusion of Arctic air masses into northern Central Asia. When these cold air masses occasionally reach the southern deserts, the temperature drops to -29°C, sometimes causing losses in stock and failure of autumn seeded crops.

Water is one of the most important natural resources in the arid zone and it is here that there is a deficiency. Rivers are not numerous and many of them disappear in the sands of the desert. Only two rivers, the Amu-Dar'ya and the Syr-Dar'ya, cross the desert in a distance of more than 1,000 km. The Amu-Dar'ya is 2,390 km long and the Syr-Dar'ya is 2,530 km in length, and they are the main natural and agricultural "routes of life" in the deserts of USSR.

The Amu-Dar'ya at maximum runoff carried about 6,400 m^3/sec; minimum in winter of 450 m^3/sec (14 times less). The total annual runoff is about 60 km^3. The Syr-Dar'ya's total annual runoff is only 35 km^3 with the same high difference between maximum and minimum runoffs. These large variations are a problem in the artificial regulation of the annual runoff.

A large amount of water from the abovementioned rivers is used for irrigation purposes, and of this amount some is lost in evaporation and filtration. The Aral Sea receives only 60% of the Amu-Dar'ya runoff and 37% of the Syr-Dar'ya runoff. All the rivers of Central Asia have a total annual runoff of about 159 km^3, 30% of which is lost in evaporation and filtration.

The water supply that may be potentially used for irrigation is therefore about 110 km^3 per annum. In Central Asia at present about 60 km^3 per annum is used for irrigation, and there is the possibility of further developing irrigation.

The underground waters are also of great significance. They are widely distributed throughout the desert, especially beneath the ancient alluvial lowlands such as the Karakum desert. The level of these subterranean waters fluctuates between 1 - 2 m and 100 - 200 m. The salt content varies but generally the water is suitable for watering sheep and camels. There are also lenses of fresh water originating from rainfall. Thousands of wells constructed in ancient times are scattered far from the rivers in Central Asia and support the grazing industry.

The desert soils are of the grey soil type, very pale in colour, and contain low levels of humus ($<$ 1%). All vegetation sites are quickly mineralised. However, desert soils in the vicinity of foothills contain high levels of nitrogen (N) and are very fertile under irrigated conditions.

Desert vegetation is necessarily extremely adaptable to arid conditions. Large shrubs develop a huge root system allowing them to reach moisture to a depth of about 20-25 m. Sideways roots keep the plant stable during periods of sand movement.

Short grass vegetation uses rain water to a depth of 0-20 cm. Following the period of rainfall all grass vegetation dries out and remains in seeds (ephemers) or in roots and bulbs (ephemeroides).

Most of the vegetation biomass in the desert develops into shrub vegetation of Haloxylon species. On the basis of this shrub a "forest industry" can be organised in the desert. Grass vegetation (Carex, Poa) dries out but remains stable throughout the year and is like "hay on the root". It supplies fodder all year for grazing sheep in the desert.

Animal populations in deserts are represented by many ancient species, which are also highly adapted to these extreme conditions. Highest population densities are in sand deserts, and psammophyl animals are adapted to the moving substrate structurally and behaviourally. Many species burrow into the soil or use the burrows of other animals e.g. mammals, reptiles and insects. Many animals prefer nocturnal habits, thereby escaping the extreme heat of the day. Mammals are represented mainly by Meriones and Rhombomys; reptiles by Eremias, Agama, Geckonidae; insects by Tenebrionidae and Scarabaedae.

Ecosystems in deserts are combined with fewer blocks than in humid regions, e.g. in forests. One of the groups of blocks in sand deserts is described in Fig. 5.

Because of restricted blocks and comparatively low level density, ecosystems in deserts are much more vulnerable than ecosystems in other habitats. Removal of one of these blocks would severely damage the ecosystem because in arid conditions there is almost no possibility for connecting blocks to switch on in other directions. By reducing the population it is easy to reach a critical level of density, after which a species can be eliminated entirely.

Some species in the desert zone are important for sport and for industry - antelopes, saiga and jeiran, desert hare, fox and cat (native desert cat). During spring and autumn the rivers and lakes are full of wildfowl moving through the desert to their nesting or wintering places. Recently, the milking of venomous snakes for medicinal purposes has developed and there are now 5 snake farms in Central Asia.

The deserts of the USSR act as national parks and reservations and in this way all types of deserts in their quasi-natural condition are conserved. Of the 93 national parks and reservations in the USSR more than 10 are situated in the desert zone. The main natural reserves are on the south east Caspian shore - Gasan-Kuli (for wintering wildfowl), in the Kopet-Dag Mountains - Badkhyz (mainly for kulan, arkhar and wild mountain goat), in the Karakum desert - Repetek (for sand desert animals). Many scientific institutions are investigating the problems of conservation and utilisation of natural resources in deserts and the leading institution is the Scientific Institute of Deserts of the Academy of Sciences of the Turkmenian SSR situated in Ashkhabad.

Utilisation of natural resources in Central Asia is directed mainly towards the grazing industry and irrigated agriculture. These occupations have existed for many centuries, and the utilisation of mineral resources is comparatively new.

Irrigated agriculture has a long history and a wide distribution. The peoples inhabiting Central Asia in ancient times instituted the large areas of irrigated agriculture, i.e. the oases, in the valleys and deltas of the desert rivers. The total length of the irrigation channels in Central Asia now amounts to some hundreds of thousands of kilometres.

The irrigated lands support industrial as well as sustenance crops. Plantations of fruit trees such as peaches, apples, prunes, apricots and subtropical species - granat, inzir, mindal, maslines, are common. Vineyards are also widespread. However, the major portion of the land is assigned to the most important industrial crop - cotton. Of the land under cotton, 1669 thousand ha are in Uzbek SSR, 312 thousand ha in Turkmen SSR, 242 thousand ha in Tajik SSR, 74 thousand ha in Kirghiz SSR, 45 thousand ha in Kazakh SSR. The annual crop in Uzbek SSR produces 3861 thousand tons, Turkmen SSR 692 thousand tons, Tajik SSR 626 thousand tons, Kirghiz SSR 140 thousand tons, Kazakh SSR 90 thousand tons. The total annual cotton crop in the USSR is 6 million tons - the crop from 1 ha being 24.5 centners, the highest level in the world.

The abovementioned crops all require artificial irrigation and therefore a network of irrigation channels was developed. It is important to point out that prior to the October revolution these irrigation channels had been adapted to the requirements of private property owners who had tenant farmers. Following the October revolution, all land was nationalised, large collective farms were organised, and the network of irrigation channels was reconstructed, to cope with the changed rural structure and the introduction of different crops.

On the Tejen and Murgab Rivers a chain of large water reservoirs was constructed. These reservoirs prevent the water runoff from entering the spring, and allow the water to be used slowly through the dry summer.

In addition there have been built large main water channels for irrigation purposes. The largest of them is the Karakum channel, presently under construction, whose origin will now be detailed. (Fig. 6).

At the end of the nineteenth century the famous geographer academic V.A. Obruchev discovered that an ancient valley of the Amu-Dar'ya River. The project was begun in that year and 5 years later the first part of the channel, a length of 400 km. was completed. The water from the Amu-Dar'ya then reached the Murgab oasis. This section of the channel carried 35 km^3 per annum and allowed an increase of 100,000 ha in the irrigated land in the Murgab oasis.

The second part of the channel, from Murgab to Tejen, was completed in two years and extended a further distance of 140 km. Water consumption reached 4.7 km^3 per annum and the amount of irrigated land in the Tejen oasis increased by 60,000 ha.

In 1962 the third part of the channel, a distance of 285 km, from Tejen to Ashkhabad was completed and two large reservoirs were contained in this third section.

A keen appreciation of the hydrogeographical peculiarities of the territory made possible the construction of a channel without dams, with natural flow of water. In the reservoirs during winter, water accumulates and adds 30-35% to the summer runoff.

The water resources of the Karakum channel are used in a complex way. Firstly, for irrigation of agricultural land whose chief product is cotton. Secondly, the channel has an important transport role, connecting the Kerki,Murgab and Tejen oases to Ashkhabad, the capital of Turkmen SSR. For Ashkhabad with its population of 253,000, the Karakum channel is an important source for the water supply and in addition is a magnificent recreation area. Hydroelectric power stations are presently under construction on the channel.

The main use of the channel is for irrigation. Today it provides water for 360,000 ha of new farmland which includes 160,000 ha used for cotton cropping. In the near future the area of irrigated land in the channel area will reach 1 million ha, and in the whole scheme there is a possibility of irrigating 2-3 million ha if all the water is used to supply the remote pastures of Karakum. Therefore many long-distance pipelines are being built.

Construction of the channel has eliminated the disastrous consequences of drought years in cotton growing area.

The Karakum channel has greatly improved agriculture and the standard of living for the population of Turkmen SSR. The fourth and fifth parts of the channel are now being built and when completed, the channel will be 1300 km long. One branch will reach the shore of the Caspian Sea near the town of Krasnovodsk and the other will extend southward to the Turkmenian subtropical area. This will be the longest gravity-flow shipping channel in the world. It will also serve as a waterway from Central Asia to the Caspian Sea, and thence to the Black, Baltic and White Seas.

The Uzbek SSR also has a highly developed irrigation system whose total length is 130,000 km. The longest channel in the complex is the Great Ferghana Channel which is 270 km in length. Large-scale development of the Hungry Steppe, the extensive area of desert between Samarkand and Tashkent oases, is now underway. The area has been widely provided with canals and cotton fields, orchards and vineyards are productive on the more than 400,000 irrigated ha. Now only the name, "Hungry" Steppe is a reminder of ancient times.

The total area of irrigated land to date in Soviet Central Asia is in excess of 6 million ha.

One interesting and novel source of water supply in Central Asia is the glacial ice from the mountains surrounding the desert. The total area covered by the glaciers is about 2000 km^2 and the volume of water in the ice is about 2000 km^3. All the glaciers of Central Asia produce a total 22 km^3 runoff. Scientists from the Institute of Geography of the Academy of Sciences of the USSR are investigating methods of increasing the runoff from glaciers. One of these methods involves covering the surface of the glacier with dark dusts, which causes an increase in melting of ice. This method, it is hoped, will possibly increase the runoff from the glaciers in years of drought by 30-50%.

The grazing industry is advanced in the deserts of the USSR. The total area under pasture in Central Asia is more than 200 million ha, with 142 million ha in Kazakh SSR, 21 million ha in Uzbek SSR, 30 million ha in Turkmen SSR, 8 million in Kirghiz SSR, and 3 million ha in Tajik SSR. This area supports about 52 million sheep - 30 million in Kazakh SSR, 6.9 million in Uzbek SSR, 3.8 million in Turkmen SSR, 9 million in Kirghiz SSR, and 2.1 million in Tajik SSR. There are also more than 250 thousand camels - bactrians in northern deserts and dromaders in southern deserts.

The pastures in deserts are used throughout the year. The average annual dry weight grass crop is 100-350 kg/ha. One sheep consumes about 500 kg dry weight of grass annually. Thus, there should be 5-6 ha of pasture for 1 sheep. The main grazing areas for karakul sheep and camels are the sand deserts of Karakum and Kisilkum, with vegetation of ilak (Carex) and mixed grasses. The main water sources for herds are ground and rain water. Concrete walled wells which mechanically raise water have been constructed. Until recently some 90 million ha of pasture was deficient in wells, and in the areas close to the oases overgrazing occurred. In those areas where ground water is at great depth, pipelines provide water from the water-rich areas.

The total wool crop in Central Asia reaches more than 140 thousand tons with 81.5 in Kazakh SSR, 20.0 in Uzbek SSR, 12.2 in Turkmen SSR, 24.5 in Kirghiz SSR and 4.7 in Tajik SSR.

The timber industry in Central Asia is based mainly on the shrub vegetation of Saxaul (Haloxylon). The black Saxaul reaches a height of 7-8 m and has a diameter of about 1 m. The wood is very hard and does not float. It has a high heating value of 3.6 kcal per m^3. The average quantity of wood from 1 ha is 2 tons (maximum 40 tons per ha) and the total area of Saxaul forests covers about 20 million ha. This produces a wood crop of about 35 million m^3. As a result of

lengthy exploitation the Saxaul forests in some areas are devastated and in these areas, artificial plantations are used. The practice of reforestation is now also used for preventing the movement of sand dunes and for establishing the banks of irrigation channels. Plantations of different species of poplar tree and Elaeagnus sp. along the irrigation channels prevent infiltration of channel water into the cotton fields, and also prevent the possibility of raising ground salt water to the surface. These plantations may also be found along the railways and around settlements.

The mining industry plays an important role in the utilisation of natural resources, but details of this should be the object of a special report. It will suffice here to say that there are highly developed oil and gas industries, copper, iron ore, mirabilit and sulphur mines. A gas pipeline, 2160 km long, carrying 7-8 billion m^3 gas per annum, runs through the desert. Huge hydro-electric power stations have been built in the Pamir and Tian-Shan Mountains. They supply cheap electricity and assist in regulating runoff of the mountain rivers to irrigate the desert lands. The Nurek hydropower station now under construction, has a dam 285 m high and a capacity of 2.8 million kw. The water reservoir will hold more than 10 km^3 water. The total output of electricity in the republics of Central Asia is more than 55 million kw/hrs with 31 million in Kazakh SSR, 16 million in Uzbek SSR, 1.8 million in Turkmen SSR, 3.6 million in Kirghiz SSR and 3.0 million in Tajik SSR.

This review of development in utilisation of natural resources in the arid zone of the USSR reveals that the arid lands can provide a challenge in a well-organised and planned economy and that there are many possibilities for future composite development.

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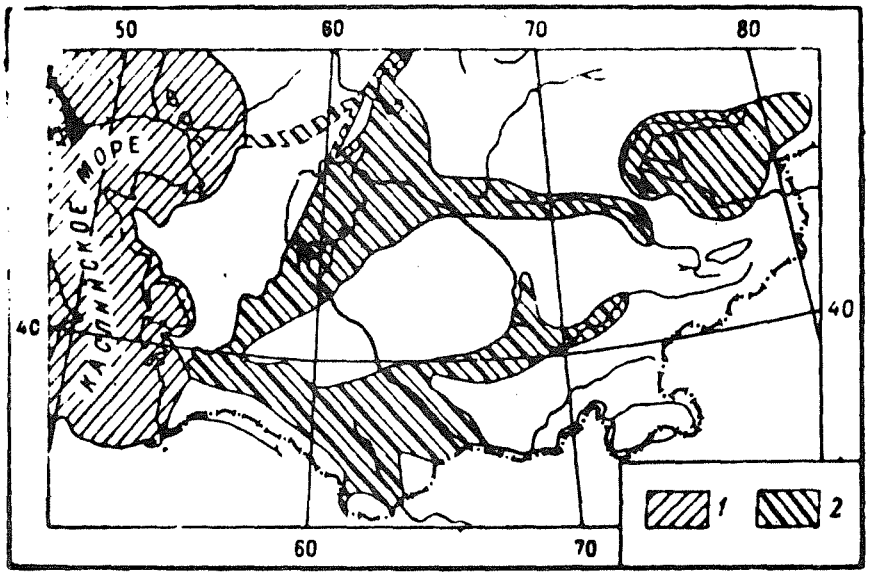
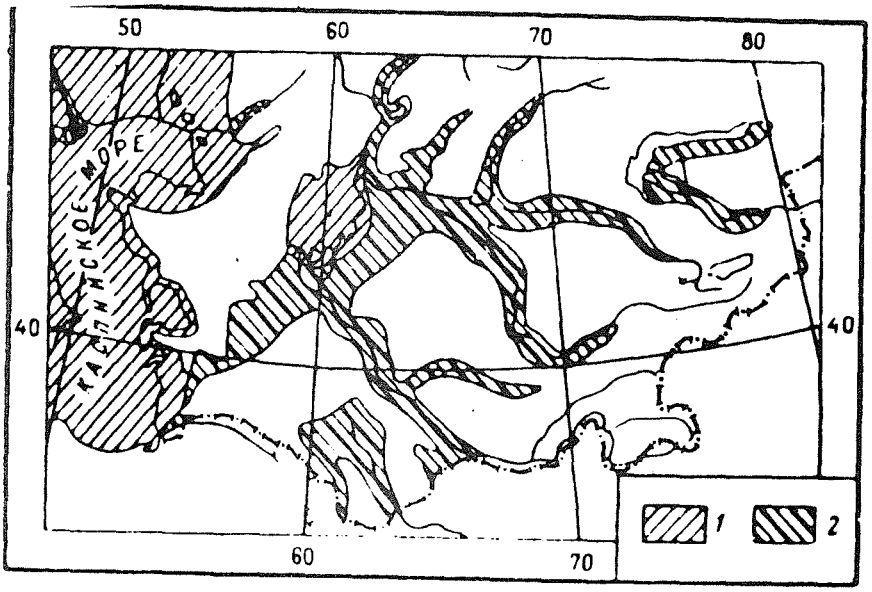


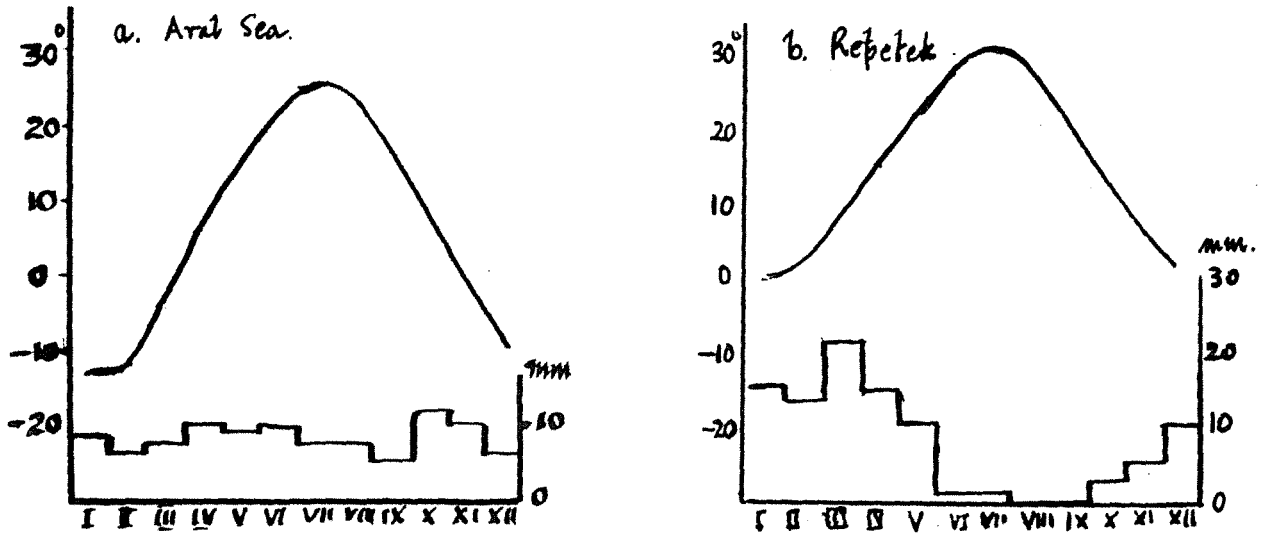
1. The Turan lowland in the first part of Quaternary.

(1) sea; (2) alluvial valleys.

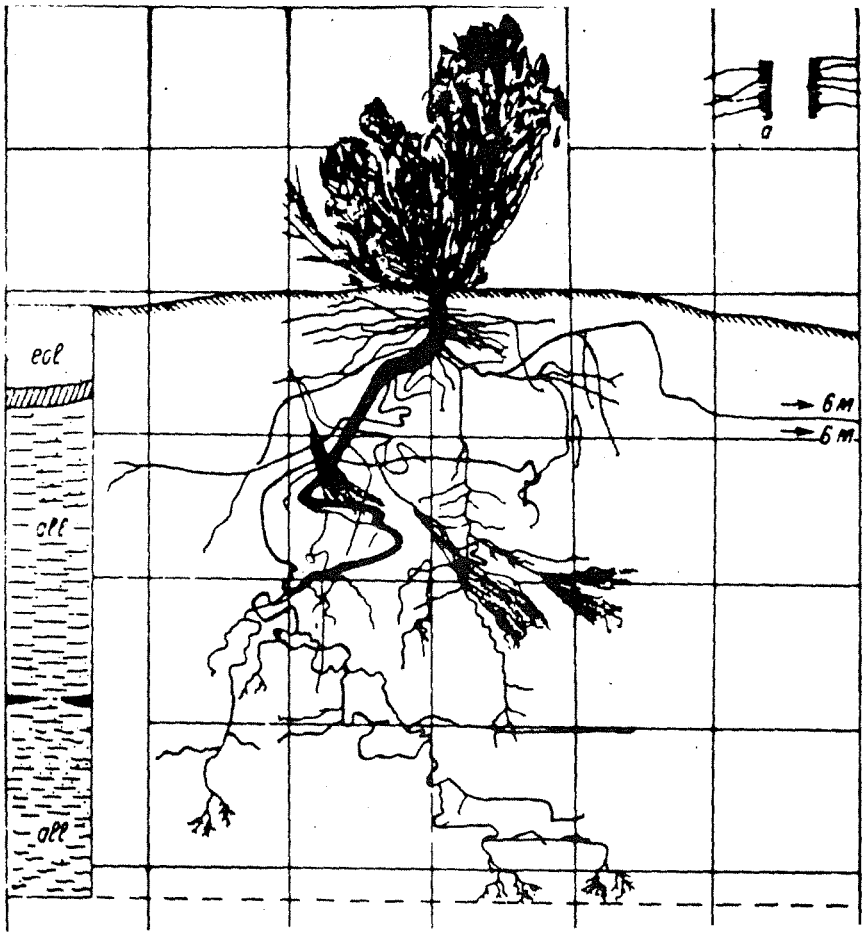


2. The Turak lowland in the second part of Quaternary.

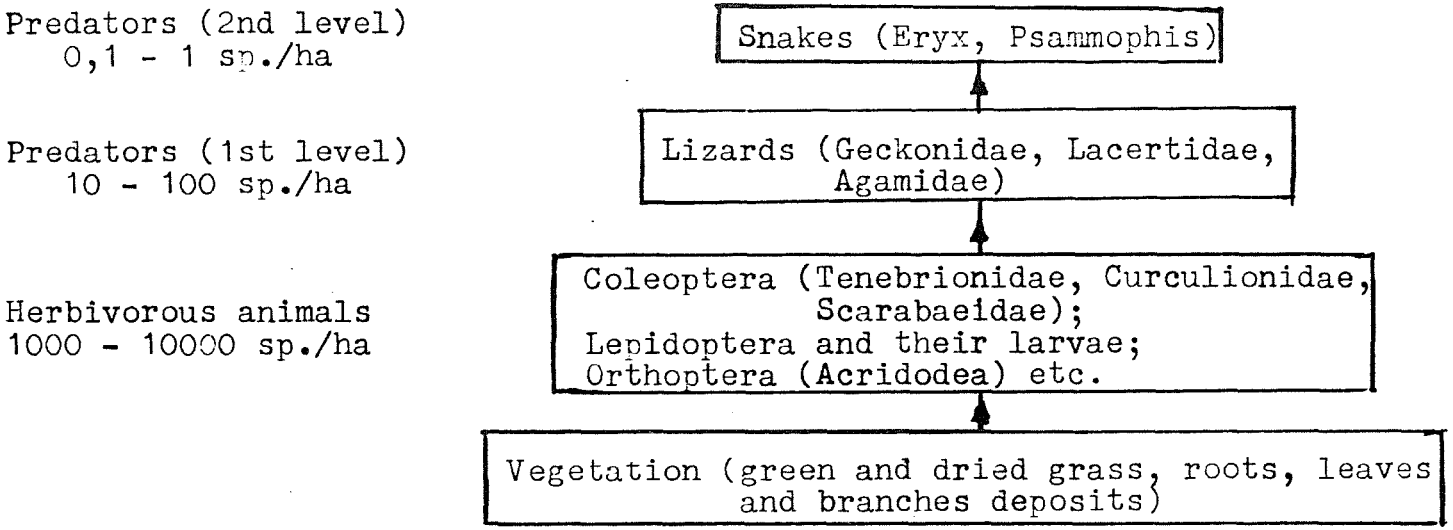
(1) sea; (2) alluvial valleys.



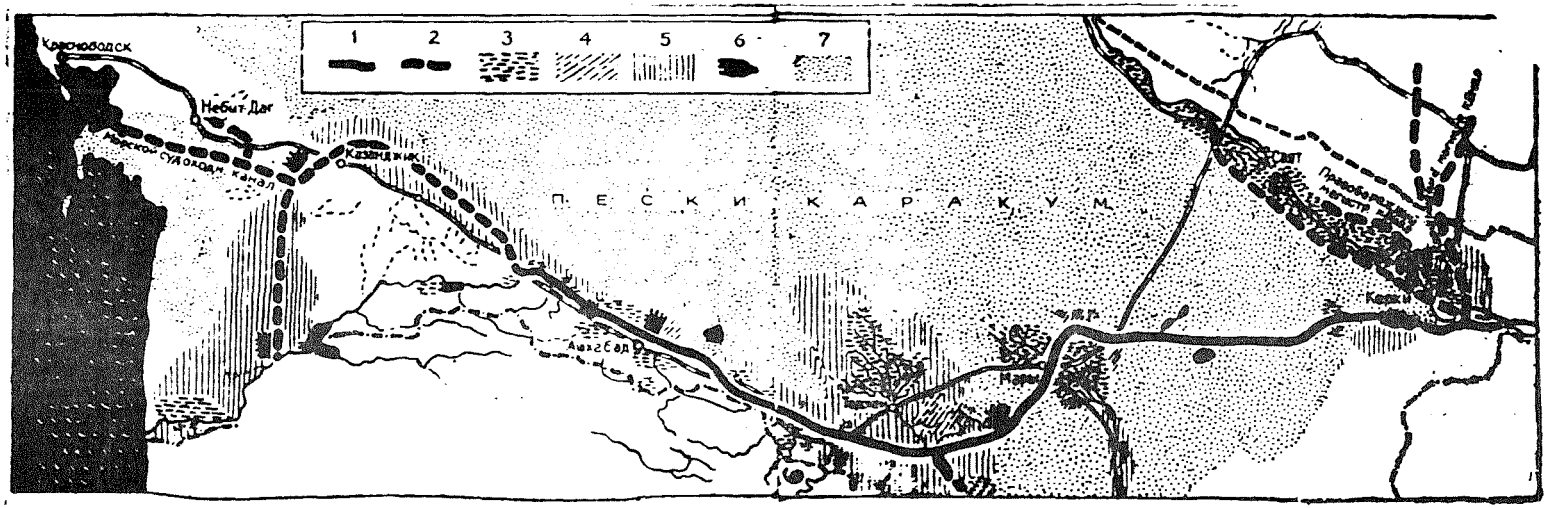
3. The rainfall and temperature in the deserts of the northern (a) and the southern (b) types (by M.P. Petrov, 1964).



4. The root system of the black saxaul (by M.P. Petrov, 1964)



5. The principal construction of the ecosystem in the sand desert (group of insects/reptiles blocks) (by N.N. Drozdov, 1965).



6. The Karakum Channel.

PROSPECTS FOR NEW ANIMAL INDUSTRIES

FUNCTIONS OF MAMMALS IN THE ARID ZONE.

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Prospects for new animal industries: functions of mammals in the arid zone.

At least 20% of the earth's surface is arid. Although the Australian share of aridity is nearer 70% of the land surface (5 million km^2) little planning has gone into the use of this territory by domestic animals. Pastoral processes were conservative rather than conservational and this has been satisfactory while the Merino could provide much of Australia's overseas buying-power. The cattle industry also, for its first 150 years made money for most operators with animals from cold temperate regions. Yet it still comes as a surprise to many from Europe that Australia is a hot country. The colonial urge is persistent however, and this sociology will continue for generations yet, in the establishment of European types of civilisation on the fringe of the continent. With the high levels of urbanisation there has been restricted thinking on the biology of the hinterland.

Aridity is a product of latitude. Australia extends from latitude 11 to $44^{o}S$. But latitudes 20 to $33^{o}S$ are between the tropical moist air circulation in the north and the wet westerly air masses of the $40^{o}s$. In between is the zone of maximum desert production. The distribution of cold ocean currents on the south and west with their associated dry air increase the aridity. These physical facts mean an environment which is hot, dry and suffused with intense radiation through cloudless skies. Much of this climatic region is not of significant use to man although some small mammals, reptiles, birds and innumerable insects inhabit the desert. There is no critical necessity for human use of the 5 million km^2 of arid country. But since it has been invaded by flocks and herds and to some extent modified ecologically, a hard look should be taken at the types of use made of this land. There is less excuse now for inefficient patterns of use of rangeland resources, as we move through the steeply exponential phases of growth in numbers and rates of use of energy and water.

Relative efficiencies. The customary livestock of the outback have been Merino sheep and Hereford or Shorthorn cattle. Only in the past 20 years have significant numbers of Indian cattle come into use. These patterns of stocking are fashions derived like mini-skirts from European or north American concepts. The fashions in South Africa are different, partly because the colony has had 200 years more experience of hot dry country and partly because there were wider ranges of indigenous animals to contrast with European imports. Effective use of veldt was increased by employing Dorper sheep, mutton Merinos or by game cropping.

The efficiency of protein production on arid range land in Australia can be estimated. There is probably an average growth of 1,000 million tons of vegetation annually in the arid country. It is difficult to set limits to aridity in this context but there are

certainly 10 million cattle and 40 million sheep in hot dry environments. Ten million cattle would consume about 15 million tons of dry feed a year and 40 million sheep about 12 million tons, a total of about 3% of the vegetation. The product yield from this food intake is also low. About half of the ingested vegetation is not abosrbed but goes back to the earth. In a flock or herd there are unproductive animals. There is a death rate up to 10% annually and these animals have consumed food without yielding a product. Up to 50% of a herd comprises cows and bulls, the breeding stock which must be maintained in order to produce meat from steers. For sheep this is not so, since all animals can yield fleece, except those which die without recovery of the skin. This zoographic (animal demographic) picture enters any efficiency determination. With cattle at a stocking density of 1 to 10 hectares (1 : 25 acres) 2 animals at least have to be fed for 3 to 4 years to yield 1 carcass. That is, some 10,000 kg of food are eaten to provide 250 kg of carcass or 20 kg of dry protein. Ten thousand kg of dry vegetation yeilding 20 kg of dry protein represents an efficiency of 0.2%. In wool production the whole flock produces wool keratin and in the arid country a sheep grows between 1.5 and 2.5 kg annually. For an intake of 300 kg of dried vegetation there is an efficiency of 0.5 to 0.8% for wool protein (Dolling and Moore, 1961).

In addition to the normal economic costs of such an operation there are considerable ecological costs. The flora is rapidly modified by grazing and the tracks formed by sheep and cattle, particularly in relation to watering places, make wind and water erosion more rapid, especially when the vegetation fails. Clearing is often carried out so that trees are displaced and the habitats of the 150 bird species, the 40 to 50 marsupial and true mammal species and innumerable vertebrate species of these pastoral regions are also modified, while the populations are usually gravely reduced. Fossil water is commonly drawn upon. For each animals the water cost of 1 kg of meat protein is 5 tons and 1 kg of wool protein 1 ton of water, but if the water required for the vegetation eaten is also included these water costs rise to 350 tons for 1 kg dry meat and 500 tons for 1 kg scoured wool (McMillan, 1965). Water is of course the limiting factor in production from arid country.

Animal component. In addition to the low bioenergetic efficiency of pastoral production there are inefficiencies arising from the nature of the animals used. Merino sheep are valuable animals for producing fine wool. They were selected in Spain for their ability to walk long distances and they can survive in hot dry country where British breeds like Suffolk, Romney or Lincoln perish rather rapidly. Yet in their survival there are built-in inefficiencies. Their effective reproduction rate in dry country is rarely above 50 lambs per 100 ewes each year. Twin lambs rarely thrive since the milk production of these Merinos is low and often mothering is inadequate for raising twins. This has

survival value for the ewe, since she is not so likely to exhaust herself in maintaining young. Similarly the yield of wool decreases as sheep are grazed further to the north and to the west, where pastoral land becomes hotter and dryer. Although the yield of protein is not great from Merinos they are better desert animals basically than cattle. There is reasonable evidence to suggest that cattle originated in the wet tropics of Indo-China from an animal rather like the Banteng or Guar. One line of development led to Bos indicus Zebu types in India and Africa, and the other through the Auroch became the ancestor of European breeds. Cattle have high metabolic rates and high water turnovers suited to swampy environments with steady food supplies. European breeds have been introduced to many dry areas in Australia. The cold-adapted Bos taurus animals have shown responses to arid environments more dramatic than those of Merinos. In the hot country slow growth with maturation in 5 or 6 years, infestation with ticks, failure of endocrine functions, low fertility and poor rates of milk production were characteristic of much of the early cattle industry. Slowly, adapted strains of Shorthorn and Hereford were produced and more recently Zebu breeds arrived. Some of these were not dry country types and a mixed bag of Bos indicus types has reached the herds. The Zebu certainly less demanding on water and better adapted to walk out to seek food away from water, as well as to resist the effects of ticks and high heat loads, than B. taurus is. Yet in the tropics Zebus have calves only each second year (Banteng breed annually) and many are slow growing. The Zebu is more effective in the desert partly because it has a lower metabolic rate and a lower requirement for water, partly because it is more efficient in digestion and also because of its higher resistance to tick infestation than the British breeds.

One of the interesting anomalies of pastoralism and the sociological background of Australian meat eating is the avoidance of the animals best adapted for dry country: the camel, goat and donkey, which have been allowed to run wild. Some Italian markets for donkey meat have been exploited. The use of camel meat throughout the Arab world and a good deal of central Africa has not been the subject of export drives nor has the European, African or Mexican taste in goat meat been paralleled by use of this animal in Australia. Yet the analogue of Australia in the northern hemisphere is north Africa - the Sahara and Algeria.

African pastoralism. There were two main periods of colonization in southern Africa. The first began at the Cape in the 16th Century and spread towards the tropics. The second incursion of Europeans occurred in the last 100 years mainly in central Africa, Kenya, Tanganyika and Rhodesia. Although at Cape Colony European stock were imported the settlers learned to use native animals. The Afrikaner cattle were superior in disease resistance, growth rate, food conversion and reproductivity to the European breeds in the Transvaal. Crosses were made between local breeds of sheep and imported animals. These resulted

in desert meat sheep like the Corper (Dorset x Somali Ogaden, with black head and fat tail). These sheep proved successful in the Namib desert and similar dry regions of western Africa. They were superior to Merinos in survival and reproductivity under near desert conditions. Their habitat would be comparable with the north part of Western Australia. The South Africans appreciated that on the better country (still hot and dry) a combination of meat potential with large body size and good yield of wool, made more effective use of country than the purely wool sheep. The German Merino with its greater fecundity,better milk yield and meat quality has been used in South Africa for a long time. From the beginning some degree of game cropping was inevitable as the settlers took advantage of the zebra and antelope. More recently a definite policy of conversion to cropping of game has taken place. In the Transvaal about 5,000 properties have been devoted to using buck and other forms of antelope for meat and skins.

The technology of cropping involves night shooting and trucking of animals to an abattoir for controlled dressing. There is virtually no awareness by the herds of the nocturnal human predators so the animals do not scatter from the rangeland shared with sheep and cattle. Cropping is useful in controlling the number of antelope, which have increased in many places because of the shooting out of carnivores. The operations have been profitable.

Tropical colonies like Kenya and Tanganyika have large areas of arid land and they were invaded only in the last 80 years by European pastoralists. There were monumental struggles in the first decade of this century to combat the protozoal, virus and bacterial diseases carried by a wide range of vectors to European stock. In the last 30 years the Boran (Bos indicus) has been improved to form a much more disease resistant and competent beef animal for these hot-dry regions. Nomadic herdsmen like the Samburu and Masai used Zebu cattle, Somali goats and small, haired sheep for sustenance. Since the possession of animals was essentially a sign of wealth rather than a source of directnutrients, there was little selective breeding. The increase in population of the nomads with introduction of penicillin and medical care has resulted in considerable over-grazing and competition of sheep and cattle with zebras, antelopes and giraffe. Eland and kongoni with their high fertility could be domesticated. This is possible also with warthog, buffalo, or blesbok (Jewell, 1969).

Population density and meat production. The biomass of mammal living on the hot-dry plains of South and Central Africa reaches higher levels with the indigenous animals than with European types of animal husbandry. Talbot (1964) estimates that up to 10 times more wild ungulate than the cattle, goat, sheep domestic animal complex can live on the Kenya savannah. In this tropical grassland animals like the eland, kongoni and wildebeest achieve live weight gains twice those of even the Boran type of cattle. The live weight gains are not high, averaging about 0.15 kg/day over 3 years for cattle and 0.32 kg/day for the eland. Over 2 years, wildebeest

and kongoni have an average gain of 0.2 kg/day. These averages, of course, include the periods of drought which intervene annually between periods of plenty.

Ledger (1968) summarised many years of investigation of the carcass quality of antelope, buffalo and hippopotamus relative to sheep and cattle. The essential findings are that amongst antelope carcass weight averages between 50 and 65 per cent of the live weight with a mean of 58 per cent while Bos indicus cattle are generally about 57 or 58 per cent. A further difference is that antelope have 1 to 5% of fat while Boran steers contain 12 to 13 per cent of fat. The lean weight of the carcass as a percentage of the carcass weight is different therefore between the antelope (mainly 79 to 82 per cent lean) and Zebu cattle at 54 to 68 per cent lean. The laying down of fat requires twice as much effective food intake as protein. Metabolic efficiency of eland relative to Boran cattle has been studied by Hopcraft (personal communication) in Kenya. Nitrogen retention and digestibility of the savannah grasslands in antelope seems to be greater than in Boran cattle. The full picture of zoographic efficiency, density effects, disease resistance, life expectation and metabolic and endocrine competence, fecundity, milk production and similar questions have not yet been worked out. But it does appear that more antelope can live on a given piece of territory without destruction of the environment, producing lean meat which makes them a rational animal protein crop.

Russian experiments. In 1892, 4 male and 4 female eland were taken to the Ukraine (Treus and Kravchenko, 1968) and although winter temperatures are cold, over 400 eland have been reared from the original stock. The eland females have calves each year, gestating 255 days. These animals have, in the cold temperate climate, a spring coat-shedding pattern. Some mating takes place at all times of the year as would be expected of a tropical animal but maximum conception occurs in summer. They lactate for 8 months, producing up to 600 kg milk containing about 11% of fat and 7% of protein.

The eland have adapted well to the non-tropical environment and would probably adjust rather better to some of the less arid parts of Australia.

In Russia the Saiga antelope was almost extinguished by hunting 50 years ago. A policy of conservation was employed so that in the course of 30 years a herd of some 2 million was built up on the Steppes. From this population each year about 6,000 tons is cropped, mainly younger males and older males and females, shot and processed in field abattoirs.

Ecological background of ungulate production. Although antelope and similar animals are efficient in tropical and arid grassland there are associated problems of control once human intervention occurs. The hunting of predators such as lions and hyenas has resulted in a series

of ungulate over-population problems in both South Africa and Tanzania. The great proliferation of kob in the Serengeti has human origins. A similar state of over-population has occurred with elephant and hippopotamus in Uganda, and buck in the Kruger National Park. Once the predator pressure is altered very rapid changes in population occur, since antelope can proliferate at more than 15% per annum.

In addition to the population as such changes are induced in the environment by high-density living. The elephant of East Africa are in ecological balance in the more mountainous country where there is little human interference. When, however, elephant were confined to smaller territories on the plains the population built up and trees were destroyed. The elephants ringbarked trees in seeking food so that forest converted to grassland. Elephants were then exposed to intense irradiation from the sun and their burnt skins led to further scratching against and destruction of trees. Sikes (1964) suggests that disturbances of calcium metabolism occur when elephants are forced into grassland environments and this leads to deposits of calcium in the blood vessels. The forest elephants were almost free of arteriosclerosis while those in the lowland parks have heavily calcified blood vessels. The possibility of excessive production of vitamin D in the open sun lies behind the calcification of the aorta and this, combined with the social pressures and considerable fighting, lead to a very human type of pathological process. A change of environment can, thus, have complex functional consequences.

The arid Arctic. In Alaska there are 250 thousand hominids and some millions of large mammals such as caribou, moose, bear, wolves and mountain sheep. Eskimo lived in good equilibrium with these mammals as well as with seals and whales until the last 100 years. With Russian firearms the killing rate increased rapidly, and even more steeply after the American purchase . The Eskimos began commercial whaling but the Arctic and Bering Strait whales were reduced by the 1930's to levels where whaling had to cease. The musk ox was eliminated from Alaska. Now polar bears and Dall sheep are precariously low in population with inadequate replacement rates. Thus in Alaska the need for a well orientated and monitored wild-life service showed very clearly. Both state and federal wild-life protection services drawing manpower from Universities (where the ideas of ecological balance are studied and taught) have developed in Alaska and Canada. Hunting is licensed. The price of killing a Dall sheep in the Alaska range is about $2,000. There is poaching, but there is also reasonable monitoring of populations so that some restoration of the balance under human guidance is possible. Yet wolves are still killed on sight with $100 bonus offered for each scalp. The control of caribou herds then devolves even more on human operations. The essential point about the Arctic desert fauna now is that its life and death is very largely in human control. By considerable

efforts the musk ox has been restored to a population of about 1,000 on one island, while on another a small colony of caribou in the course of thirty years reached a population climax and crashed in the absence of predators. There are many lessons to be learned from this by any country like Australia where wildlife is undergoing transition from a balance in the absence of human pressures to a state where competition with ungulates and man is inescapable.

Australian potentials and problems. The 5 million km^2 of pastoral lands comprise Mitchell grass (Astrebla spp.) plains, spinifex (Triodia) and saltbush (Atriplex and Kochia)as well as Acacia scrubland, in latitudes from 20 to 35^{o} S. Even in the tropics there is an 8 month long dry period following the summer rain. In the Centre there can be droughts of many years duration, such as the 1957-1965 drought which resulted in the removal of virtually all cattle from the Centre.

In the arid environment, water metabolism is important. The relative rates of water use by sheep and cattle are shown in Table 1. Sheep are less water dependent than cattle, and the fleece insulates them against radiation, while Zebu cattle reflect energy from the shiny coat.

There are physiological hierarchies of water turnover amongst desert ungulates. Those with high rates of water use, like cattle probably migrated to dry country, where they die rapidly without water. Intermediate groups are sheep, kongoni and goats. The most desert adapted (probably evolved in Pliocene deserts) live for weeks in summer without water - camel or oryx (Table 2.)

Marsupials. There has been intermittent talk of kangaroo farming for many years. Over the past 15 years at least 500,000 kangaroos have been killed annually for pelt and pet meat on an almost unregulated basis. At least 12 species of marsupial have become extinct since hominids arrived in Australia so there is no doubt about the need for biological regulation. The information for such control is slowly accumulating. The only types of marsupial of which there is sufficient biomass to justify cropping are the red and grey kangaroos, the wallaroo-euro and possibly the agile wallaby of the tropics. Average population densities of kangaroo seem rarely to rise above 1 to 5 per km^2 (Newsome, 1965). Although there are analogies between kangaroo and antelope their densities are very different and nothing like the great upsurge in biomass found amongst kob in the Serengeti seems to have occurred in Australia.

Physiologically the macropods are not remarkable desert animals. They have the advantage of a lower metabolic rate than eutherians of the same size but they lack effective cooling systems and so escape the heat of the day by behavioural methods (Ealey, 1967). Red kangaroos stay

under the shade of scrub trees while euros and many wallabies shelter in cave or rock shadows. In dry country their survival comes not from powerful renal mechanisms but rather from the selection of succulent vegetation or fresh grown parts of grasses and forbes. Ruminant functions are poorly developed in marsupials so that there is less breakdown of cellulose fibre in macropod stomachs than in the sheep or cattle rumen. Water requirements are of the same order as those of sheep.

There are two advantages of kangaroos from the cropping point of view. One is that the hind leg muscles form a mass of lean meat which is greater than that obtained from a whole Merino sheep of the same weight. Both sheep and cattle lay down more fat and less protein than kangaroos on the same pasture, a feature similar to that of the antelope in Africa. The other advantage is the auto-regulation of population by delayed implantation of blastocysts, if food supplies fail (Newsome, 1966). Their rate of growth, however, is no greater than that of sheep and maturation is not common before $2\frac{1}{2}$ years, which places them between sheep and cattle in this respect (Newsome, 1966). There is some overlap in food choice between sheep and kangaroos (Griffiths and Barker , 1966) but on the whole there is a satisfactory difference of feeding pattern between the two animals.

Considerably better use of the half million macropods taken annually could be made by employing field abattoirs like those of the croppers in Africa, so that the meat is officially acceptable for human consumption. Since neither numbers nor functions are outstanding amongst these animals as a protein resource, more care and thought to their status in the evolutionary pattern and their potential for interesting visitors from continents without marsupials, seem the appropriate attitudes.

The most competent desert animal introduced to Australia so far is the camel, which has worked in the outback for 110 years (McKnight, 1969). Its physiological characteristics, which may be looked on as a model system for choosing animals for the arid country, include a very low metabolic rate, low water turnover, conservation of plasma volume when deprived of water, a fat store of energy which can last nearly a year, a winter coat which is shed in spring to produce a reflecting surface, feet which do not open pathways to erosion, a wide range of dietary tolerance and tolerance of 5.5% salt in drinking water (Schmidt-Nielsen, 1964; Mcfarlane and Howard, 1972) These provide mechanisms of survival in a desert which are excelled only by some of the antelope such as addax and oryx.

In the search for animals which might make most effective use of the semi-desert areas for supplying protein, antelope are obvious candidates. Besides the addax and oryx, the gerenuk, kudu and kob are the most likely animals to thrive in dry country. They are all relatively fertile with

good rates of gain and they have a high proportion of lean meat in the carcass. The main problem associated with them, apart from importation, would be control since there are no predators other than the dingo and man for the task.

Uses for exotic breeds of sheep and goats. The exponential upsurge of polyester fibres (which have doubled in output each 3 years since 1953) has encouraged a search for other animals to use the wool growing lands. There is interest in the angora goat, as there was many years ago in the llama and alpaca, but these fine fibres are likely to have only a limited market.

There are four main products that could be considered :

(1) carpet wools (2) alternative edible proteins (3) milk and cheese (4) tourism.

Carpet wool importations to Australia reach more than 6 million kg annually and certainly local carpet making is increasing, as is the social pressure for wall-to-wall demonstrations of opulence. For making carpets, both coarse wool and hair are useful with fibre diameters between 35 and 45 Ossimi sheep from Egypt, the Awassi from the Middle East and Bikaneri from Rajastan all have potential in this respect although their clean wool yields are only 1 to 2 kg annually. Reproductive performance on the other hand, is a good deal better in the dry regions (100 to 140%) than is the record of most Merinos in Australia. Some export of carpet wools is possible since there appears currently to be a world shortage and the polyesters do not adequately replace wool in carpet manufacture.

Israel has successfully turned the flocks of Abram (Awassi's which yielded about 100 l. of milk per lactation) into highly productive animals with up to 1200 l. per lactation. Sheep cheese is a sufficient luxury to make this a profitable enterprise. Goat cheeses are also likely to have larger markets since, in rich countries, eating relates more to requiting emotional and social needs, than to nutrition.

Protein. The fall in wool prices has sensitized every producer and consumer to the dangers of a monoculture for wool. The South African approach to using the veldt for mutton Merinos is a reasonable example to follow and importation of animals of this type could considerably alter the economics of some of the smaller sheep producing areas. Animals like the Romanov and Stavropol Merinos of Russia have higher fertilities than Australian breeds and produce useable lamb or mutton as well as wool. In South African experience they appear to be reasonably tolerant of heat and drought.

The Merino is probably not as drought-resistant as some of the fat-tailed sheep like the Ogaden of Ethiopia-Somalia (the black-head Persian). A cross between Ogaden and Dorset (the interesting British

breed with low water turnover, relatively low metabolic rate and independence of photoperiod for breeding) has produced the Dorper. This has a good record of meat production in desert conditions and it is a very vigorous animal. Introduction of either the Ogaden or of the Dorper could contribute to the meat industry from sheeplands. The advantage of sheep in this context is that if they have useful fecundity, lambs can be produced and relatively quickly fattened during the wet season. Even if the sheep are used for meat after one year they do not have to go through the 3 years of increase and decrease of weight characteristic of raising cattle in arid country.

Fecundity is poor but in the desert of Nubia, which has the same latitudes as northern Australia, there are hair sheep breeds such as the Meidog and Kababish, with reproduction rates of 130 to 150%; although these animals look rather like goats a cross to the Merino might well increase the yield of lambs and with that, sufficient milk and mothering instinct to rear a lamb and a half per ewe.

The potentials of Bikaneri sheep of Rajastan are still being investigated but they have good fertility. They would contribute desert hardiness to wool producing sheep and if combined with high milk potential such as that from the fat-tail Awassi lamb and mutton could be grown on some of the wheat/sheep complexes of the hotter areas of South Australia and Western Australia, as well as carpet wool.

Goats. There are 350 million goats, mostly in the tropics and sub-tropics (Devendra and Burns, 1970) where they provide milk, hide and meat. Tropical goats crossed to Anglo-Nubians can yield more milk per kg than tropical cattle or buffaloes.

There is increasing evidence that when pastures have been eaten out by sheep and cattle, goats remain as survivors, rather than as the prime cause of vegetation loss.

Goats are by no means uniform in their physiology. The Saanen is essentially Swiss, with less desert tolerance than the Somali goat. In the Sinai desert there are small goats which have more than one kid annually and yet use 30% less water and energy than the normal goats of Israel (Maloiy and Macfarlane, 1972). A combination of these genes with Anglo-Nubian could lead to a useful source of protein. There is the sociological difficulty of consumers becoming accustomed to goat meat but with the universal hamburger penetrating the social scene these differentials could readily be lost.

Stocking rates can be and should be regulated to food supply as in any other method of using dry rangeland.

Cattle. Although some Bos indicus breeds have been introduced into Australia (Afrikaner from South Africa and American Brahmans, with a few Sahiwals) there has been no systematic importation of the desert types in this species. The experience in Kenya with Boran cattle indicates that they are not only disease-resistant but also drought-resistant and tolerant of heat. The potential of the improved Boran should be investigated under Australian conditions.

One of the most rapidly growing industries in the world is tourism and all governments are looking to this exploratory behaviour of primates for profit. The great pleasure of travel in Africa is the variety and easy visibility of a large number of delightful mammals. In Australia the tourist has to struggle to see a kangaroo or emu if it is not in captivity. Yet these animals provide the heavily imprinted preconceptions of the continent,which exist abroad. In Africa the main hope for the preservation of a balanced mammalian ecology comes from the tourist (although the tse tse fly has protected indigenous mammals from the incursions of sheep and cattle in some areas).

The uniqueness of the marsupial fauna should increasingly be its protection, since world curiosity about marsupials and awareness of them could develop further. Like urban traffic problems, the tourist and the camera are inescapable aspects of the 1970s and they are the most effective forces for conservation of marsupials, other mammals, birds trees and plants in this continent.

Problems. The two main difficulties relating to the use of more exotic animals in Australia are that functional and productive capacities are still only partly understood, and the resistance to importation has not yet ceased. Both of these positions are being clarified, however. Interest in African animals and their functions has grown exponentially over the last 10 years.

On the importation side the Federal Government's quarantine attitudes have been rigidly maintained for 14 years. Since 1968 fear of the blue tongue, rinderpest and foot and mouth disease viruses has prevented contact with the outside world at the ruminant level. Australia has been the isolated continent in this respect: even New Zealand has found ways of introducing Charolais and Landrace genes, while Australia waited. There is now a Committee concerned with advising on the types of animals which might be introduced to alter the genetic background of livestock already in the continent. Officially the policy on introduction has not yet changed appreciably although semen is coming in after being frozen for 2 years. The possibility of setting up an island quarantine station is now much nearer fruition than it has been for a decade. With these possible introductions the need for further exploration abroad and for adequate physiological study of the incoming animals becomes

greater. We were able to make some observations in this field (Macfarlane et al. 1971; Macfarlane and Howard, 1972) but a good deal more should be understood before the final selections are made.

It is interesting that South Africa has been exporting animals from blue tongue virus country for many years. Mutton Merinos have been sent to Uruguay and the Argentine after periods of isolation in the Transvaal. No virus has been introduced to South America by these means. The technology for moving virus-free animals exists and has worked successfully. It can be applied in Australia.

Other technologies of course are in action. The frozen semen approach to introducing genes has begun, with Charolais sperm already in Australian cows. The difficulty here of course is that only the male genes are imported. Fertilized eggs of sheep and cattle have been transported from Britain to Africa as blastocysts implanted into carrier rabbits. These provide male and female sets of chromosomes so that a purebred animal can be obtained. The carriage of rabbits is less expensive than moving cattle across the world though there is a minimal risk of blue tongue in the fertilized egg: so quarantine at the receiving end is involved in any Australian exercise of this type. The technological aspects of these processes are now at a level where they are quite practical without high costs.

Conclusions.

The bioenergetic efficiencies of using arid lands is low. This leads to two possibilities. One is to use this territory for the indigenous populations of Aboriginals, marsupials and birds, and for tourists.

If money must be made from dry lands by grazing ruminants, the animals likely to be optimal in their adaptation to the climates should be used. Any breed or species of mammal has some adaptability. It can stretch its functions to meet colder, hotter, poorer or richer environments. But the limits of this adaptability are small. Quicker and more effective results come from using animals adapted by millions of years of evolutionary selection to hot-dry, hot-wet or drought conditions. They have physiological competences, and after transferring them to the appropriate ecosystem they would not have to adapt further. The use of genetic material of this sort, especially when crossed to highly productive animals, seems the most rational and certainly the most rapid way of obtaining greater yields from the large amounts of semi-arid land in this continent.

With these potentials for exploitation there are equal potentials for destruction, like the two sets of arms of Kali. Any new gene pool of different animals requires new methods of handling, new methods of control and an adaptable farming population as well as methods of

communications of techniques. As in any introduction programme the local customs of animal handling require adjustment so that a pest situation does not develop. Animal production is increasingly tied to conservation and preservation of indigenous species. The skills required for the 1970s will be those of animal numbers, the induction of efficient management and controlled pasture utilisation. Optimal long-term production processes should be more important than maximum monetary gain.

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TABLE 1

COMPARISON OF PHYSIOLOGICAL TRAITS OF SIGNIFICANCE IN THE ADAPTATION OF SHEEP AND CATTLE TO ARID AND TROPICAL ENVIRONMENTS

	MERINO	SHORTHORN	ZEBU
	Ovis aries	*Bos taurus*	*Bos indicus*
REPRODUCTIVITY	1/year	1/2 years	1/2 years
Offspring per 100	30-60	30-60	40-70
SALT TOLERANCE	1.3%	0.9%	1.0%
COAT			
Surface T^{o} in sun (air 35°C)	92°C	58°C	46°C
Reflectance of coat	+	+	+++
Long-wave emission	+++	++	+
TURNOVER			
Energy turnover (BMR) kcal/kg$^{0.75}$/24hr*	55	90	80
Water turnover ml/kg$^{0.82}$/24hr*	220	500	420
Water dependence (days without water in summer)	6-8	3-4	4-5
EVAPORATIVE COOLING			
Ratio $\frac{\text{sweating}}{\text{panting}}$	0.15	4	6

* For comparison of animals of different sizes, energy turnover is related to weight $^{0.75}$ and water to weight $^{0.82}$.

Merino sheep have low metabolic rates and lose heat by long wave emission from the surface or by panting.

Zebu cattle reflect heat from the surface and evaporate water for cooling mainly as sweat. They have higher energy and water turnovers than sheep, but less rapid turnover than Shorthorn or similar cattle.

HIERARCHY OF WATER TURNOVER AMONG BOVIDS, ANTELOPES, CAMEL, SHEEP AND DASYURIDS.

	Breed species or genus		Body weight kg	Body solids % wt	Water turnover/24 hr ml/kg	Water turnover/24 hr ml/kg$^{0.82}$ ± SD	Environment
A	Boran cattle	(4)	197	23	135	347 ± 11	Equatorial
	Ogaden sheep	(13)	31	32	107	197 ± 28	desert
	Somali goats	(4)	40	31	96	185 ± 32	Kenya NFD
	Somali camels	(4)	520	30	61	188 ± 37	lat. 3°N
B	Boran cattle	(6)	417	28	76	224 ± 14	Dry
	Eland	(5)	247	20	78	213 ± 43	grasslands
	Wildebeest	(1)	175	27	53	137	Kenya
	Kongoni	(2)	88	15	52	116	lat 1°S
	Oryx	(1)	136	30	29	70	
C	Karakul sheep	(4)	31	24	111	205 ± 41	Tropical
	Merino	(6)	38	29	94	180 ± 34	grassland
	Dorper	(6)	42	31	88	170 ± 43	Kenya lat.1°S
D	Buffalo	(3)	354	21	212	535 ± 33	Wet
	Shorthorn	(4)	322	26	168	461 ± 48	tropics
	Santa Gertrudis	(2)	523	37	141	373 ± 60	Arnhem Land
	Banteng	(4)	372	23	132	348 ± 22	summer
	Zebu	(3)	532	39	121	350 ± 36	lat. 12°S
E	Reindeer	(6)	100	23	128	293 ± 65	Taiga
	Moose	(1)	186	23	111	284	winter
	Goats	(3)	70	33	52	112 ± 10	Alaska
	Musk oxen	(2)	324	34	35	99	lat. 65°N
F	Dasyurid marsupials						
	Sminthopsis	(8)	0.017	28	463	224 ± 12	Laboratory
	Dasycercus	(34)	0.087	30	134	87 ± 4	25°C

orthorn cattle contained less solids and used more water than the *indicus* es while the buffalo (*Bos bubalis bubalus*) had the greatest water turnover l the least body solids. These jungle animals from Indochina and Indonesia e well adapted to the wet tropics but they do not accumulate so much tissue per it of body mass as the Zebu type of animal (Siebert and Macfarlane, 1969).

THE MANAGEMENT OF LIVESTOCK IN ARID LANDS

W. S. Reid, F.C.I.V.

Chairman,
South Australian Pastoral Board.

South Australia has often been described as the driest state in the driest Continent and in support of this only about 20,000 out of a total of 380,000 square miles has an average annual rainfall of 13 inches or better.

This, of course, was unknown when our forebears established the Province in 1836 with settlement on the Adelaide plains, well within the higher rainfall area.

It was soon found that wheat grew well and the environment was also suitable for livestock. However, wheat farming was the main aim of the early settlers, and it is not surprising to find signs of such activity far beyond the, now known, limits of agricultural production.

Associated with all land development is an optimism and enthusiasm that the potential of the land is greater than it usually turns out to be, and so we have seen crops grown as far North as Hookina and Blinman, and the people of Hawker still talk of the wonderful crops of 1915-16. Mannahill and Farina are place names which reflect this optimism, but the old homestead ruins on the Willochra plain bear mute testimony to the policy which surveyed this country into 640 acre blocks as living areas for farming.

The land outside the agricultural area was at first known as "the waste lands" into which the early colonists penetrated with their flocks and herds and by the 1860's the North-East, the Northern Flinders Range, as far as Hergott Springs (Marree) had been taken up.

Mooloolloo Station near Blinman saw the start of McDouall Stuart's expedition to cross the Continent from South-North 1861, while Beltana Stationa was the starting point for Giles' exploration westward in 1875.

Names such as Peter Waite and Sir Thomas Elder figure prominently in these early records, and it is of interest that their descendants still hold much of the same land. It is with justifiable pride many of our pastoral lessees in South Australia can claim occupation extending over three generations.

Many of the earliest leases expired in 1888 and from then on they were generally issued for terms of 21 years. Later this was changed to 42 years. The present Pastoral Act 1936-70 is framed largely on the recommendations contained in the reports of the Royal Commissions on the Pastoral Industry 1897 and 1927, and is administered by a statutory body known as the Pastoral Board, consisting of three members. This is supported by staff comprising two inspectors, a secretary, and a typist, forming a branch of the Department of Lands. The general powers of the Board are set out in Section 15 of the Act and all recommendations are subject to the consent of the Minister of Lands.

In 1960 the whole Act was amended whereby all lessees were given the opportunity to surrender their existing leases for new ones for 42 years. Rents were raised, additional improvement conditions were applied to stations outside the Dog Fence, and revaluation of rental at seven instead of 21 year intervals were the main alterations. As a result over 90% of lessees surrendered their old for new leases.

It is considered that the Act has much to commend it, in that the term of 42 years is long enough to warrant expenditure on improvements, gives good security for investment, but at the same time does not alienate the land from the Crown in the same way as leases in perpetuity and freehold.

There is no limitation on the amount of Pastoral lease land any one person may hold in S.A. but there is limitation on the number of stock that can be depastured thereon. The maximum number can only be exceeded with the consent of the Minister on the recommendation of the Board. Should seasonal conditions justify implementing this provision it is occasionally granted, and with two inspectors in the field, and each often accompanied by a Board member, the Board is usually well informed on what is happening on any particular lease.

Referring back to the absence of limitation on the amount of pastoral lease land that can be held by one person, I was very interested when preparing this paper to come across a reference to the drought of 1865 which drastically reduced the flocks in the North East. Some were moved on agistment to the South East, while small holders of 100 - 200 square miles, suffered severe losses and were forced to give up. Peter Waite is recorded as having said at the time "a large spread of country is necessary to permit more flexibility in the depasturing of sheep, and the type of sheep to be developed should be capable of walking long distances to water and standing up to hot dry conditions where there is almost a complete absence of shade".

The Merino studmasters of South Australia certainly did their best to meet those requirements so that today there is a definite South Australian type sheep which eclipses all others in cut per head, lambing percentages, and the ability to handle roughage under arid zone conditions.

The pastoral country comes within the category of arid areas of Australia with average annual rainfall from an isolated 11 inches in the Flinders Ranges to 4" in the Lake Eyre basin, giving a general average of 6 - 7 inches.

To live in it and carry on a profitable livestock enterprise requires plenty of capital, and all the skills that have been acquired since occupation took place over 100 years ago, and any other factors science can contribute to help ensure successful occupation of these vast areas which to the outside world appear to be unoccupied.

Sheep have always been to the fore in the development of the closer in pastoral areas, while horses and cattle have been favoured further out where, except in times of drought, they are able to protect themselves from the ravages of wild dogs.

HORSES

Prior to the age of internal combustion engines there was always a market for horses, both light and heavy for industry and remounts for the Army, particularly in India.

The brand on Blanchewater, and the pistol brand on Lambina horses of more recent times were known far and wide. Woodduck Station, now part of the Peake Lease, which was well known in the days of the overland telegraph, when the repeater station was established there used to be devoted entirely to horse breeding. These noble animals have been superseded by mechanisation, and stations now breed them only for their own requirements and local demand.

Obviously horse breeding as an enterprise lost its appeal and a change over to cattle took place. Unfortunately it was not possible to muster and dispose of the unwanted animals with the result under free range conditions they went wild and produced the brumbie problem of today.

SHEEP

The running of Merino sheep (there are no other breeds or crossbred flocks) in the pastoral areas, has been governed by the ability of pastoralists to cope with dingoes and the most effective method to date has been by the erection of netting fences approximately 5 feet high.

Generally pastoralists would club together and form a Vermin District and erect a fence enclosing several properties. This would be administered by a local board and maintained by the board or each individual adjoining the fence.

As expansion took place new district boards would be formed and fences added to those existing, and so the outside fence moved further and further out until today it measures 1470 miles and extends from the Mulyungarie corner on the S.A. - N.S.W. border across the State to the coast on the Great Australian Bight, about 100 miles from the S.A. - W.A. border.

The last variation in the site of the Dog Fence, as it is now called under the Dog Fence Act, 1946 took place in 1964 when 4500 square miles embracing Mable Creek, Mt. Clarence and Balta Baltana were

included. Vermin District Boards or individual lessees still own the fence but in 1946 it was decided, due to the post war shortage of fencing material, and scarcity of labour, to concentrate on the outside fences in preference to maintainingthe netting fences now situated a long way from the frontier. This barrier is the first line of defence against dingoes and protects the whole of the State's sheep population of 19,000,000. Under the Dog Fence Act all land holders, except in the south and south-east, York Peninsula and the mid North, with four square miles or more, pay a rate which is subsidised by the Government on a $ for $ basis, and in turn this money is paid to the owners of the fence to help defray the cost of maintenance.

The Dog Fence has divided the pastoral lands of South Australia into two broad categories of land use, namely, inside sheep - outside cattle. At present there are approximately 50 stations in the cattle country, and 250 sheep properties inside, and in each case the area involved is in the vicinity of 100,000 square miles, over half the area of the State and something like 75% of the occupied area.

CATTLE

In the early days of development great store was laid on the occurrence of surface waters, and this doubtless assisted in the early settlement of the Oodnadatta district. As time has gone on, however, the water holes in the creek have silted up and more reliance has been placed on underground supplies and earth tanks or dams. Where relatively shallow subartesian water of good quality can be found all is well, but deep boring into the Great Artesian basin is very costly.

Around the turn of the century the Government did much to assist with the development of the pastoral areas by boring the water, primarily along the Travelling Stock Routes. These watering points were extremely important when the only movement of stock in numbers was on the hoof, but now with road transport their significance has diminished, but they still play a very important part in the economy of the surrounding stations.

With the development of high production pastures in the assured rainfall districts the emphasis has changed on pastoral properties from breeding and fattening cattle, to just breeding and selling off a surplus each year to supply the fact or store market as the case may be.

Road transport has meant young cattle can be marketed whereas previously they had to be kept to an age of maturity that could cope with the walk at least to the trucking centre.

Just as the collapse of the horse market saw a switch to cattle so the present dramatic fall in the price of wool and sheep is causing pastoralists to change to cattle. This is happening and recently figures showed 70 stations inside the Dog Fence now running 50 or more head of cattle compared with 40 such properties in 1960. Under the Pastoral Act a lessee may run either sheep or cattle, or both, and one head of cattle is regarded as the equivalent of five head of sheep.

One might say "in view of the buoyant outlook for the cattle industry compared with the depressed wool market why do not more change over?" To this there are many answers, but chief amongst them are as follows :-

CAPITAL OUTLAY:

To sell sheep on a depressed market, and buy cattle on an inflated one takes courage and capital. Length of time that must elapse before capital can be recouped and much can happen to the market in the meantime.

IMPROVEMENT:

Properties which have been developed for sheep are not suitably improved for cattle. In fact they are most destructive when it comes to fences, water troughing etc. Special yards have to be built.

WATER:

Sheep are much more tolerant of saline water than cattle and as much of our pastoral country relies on underground supplies with greater than 1 oz. solids per gallon and combined with salt-bush diet it precludes cattle.

COUNTRY:

Only a proportion of our sheep areas are suitable for grazing cattle as generally speaking, they do not like bush. In fact when there is nothing else in dry years they will die on it. Soft country with areas subject to flooding periodically are best suited to cattle grazing due to the flush of grass and medics which follow inundation and this combined with warmth and sunlight make ideal conditions for weight gain.

While there is a definite movement towards running more cattle on pastoral properties within the Dog Fence, this has been brought about by economic reasons, and people can do it only within their financial resources, and if their country and the water are suitable. I see it as an adjunct to a revegetative programme, but there are limits to its application.

SOIL:

The introduction of livestock must upset the ecology in any region and South Australia has now been settled long enough for these effects to be gauged and something done about them.

As mentioned earlier in this paper many of our pastoral properties are held by descendants of the early lessees and they are as anxious as any to preserve their heritage by judicious stocking and good husbandry. Concerning the actual management of livestock in the Arid Areas this is left entirely in the hands of the lessees and their managers, with the Pastoral Board keeping a watchful eye on the Crown interest - the land.

Soil conservation techniques are well known, but it was not until disc pitting came into operation, and it was demonstrated to be a quick and low cost method of treating denuded and degraded soils, that hope was given to extending their application to large areas of pastoral land on an economic basis.

In conjunction with the Soil Conservation Branch of the Department of Agriculture, Field Days have been held on stations in the North East and near Parachilna where demonstrations have been given with both disc and tyne implements. This with a minimum of the more costly contour furrowing and banking is giving very encouraging results, and it is with optimism we look forward to adoption of these methods on a large scale with a view to revegetating what now appear as scars on the landscape.

CONCLUSIONS.

During my lifetime, I have in turn lived and worked on the land in the pastoral industries. Within the Public Service I have served on the regulatory side dealing with animal health, then on the advisory side with sheep and wool. Finally over the last twenty years as a member of the Pastoral Board, and it is my firm belief that the present period of economic stress confronting the pastoral industries will pass.

Wool is still an important component of world apparel fibres for which there is a demand, but at a price.

Already station properties in the North-East have changed hands at drastically reduced values, at something like $10 compared with over $30 per sheep area four years ago.

The arid zone is problem country, but I am convinced the pastoral community will rise to any occasion to cope with its difficulties. Helped by Science, and an understanding Administration, livestock, both

sheep and cattle will continue to play a leading role in the occupation of these areas which form such a large proportion, not only of South Australia, but of Australia.

THE PASTORAL INDUSTRY IN AUSTRALIA'S ARID REGIONS

SOME FACTS AND FIGURES.

G. W. Reeves

It has been estimated that approximately 66% of the arid lands of Australia are occupied and utilised by the pastoral industry (Heathcote 1969). The "change and challenge" of much of our arid lands lies ultimately, therefore, in the hands of pastoralists and some consideration of their economic position seems warranted.

Since 1953 the Bureau of Agricultural Economics has collected on a continuing basis, physical and financial information from a sample of sheep graziers in Australia /1/. In 1965 a nation wide survey of the Australian beef cattle industry was conducted covering the period 1962-63 to 1964-65 /3/ and since then two other economic surveys of the pastoral industry in arid regions, namely South-West Queensland /5/ and the Alice Springs District /9/ have been completed. This article draws on relevant data from these sources in presenting a brief outline of the economic position of the pastoral industry in our arid regions.

Pastoral Industry in Perspective

Livestock Numbers: In 1961 the arid and semi-arid regions of Australia (1) supported 32% of the nation's beef cattle population and 22% of the sheep population. By 1969 these proportions had fallen to 26% and 20% respectively, largely as a result of the more rapid expansion in livestock numbers, particularly beef cattle, in the more climatically favoured regions of the continent. Both sheep and cattle numbers in the arid zone increased at an average annual rate of less than 1% over this period.

Value of Production: It is estimated(2) that over the period 1965-66 to 1969-70, the gross value of rural output derived from the arid zone was between 7-9% of the total gross value of output from all rural industries. In 1969-70 this amounted to approximately $265 million.

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(1) These regions are difficult to define in the geographical sense. The boundaries adopted in this paper are similar to those given by Perry (1969). For the sake of brevity, arid and semi-arid regions are hereafter referred to as the 'arid' zone.

(2) Space prevents a detailed explanation of the method of estimation. In brief the amount of wool produced in the arid zone (derived from A.S.I.S. data) is weighted by wool prices in arid and non-arid areas to give an estimate for the arid zone of about 20% of the total value of wool produced (given in B.A.E., Trends in Australian Rural Production and Exports, various issues). Seventeen percent of the value of sheep slaughterings, and between 12-14% of the value of beef slaughterings are added to this.

Number of Properties: In recent years a slight decrease has occurred in the number of sheep properties operating in the pastoral zone [3]. At present there are about 7,200 sheep properties in this zone, representing about 8% of the total number of properties in the sheep industry /1/. In 1965-66 there were about 2,300 beef cattle properties located in the arid zone but a proportion of these would also have been classified as sheep properties /10/. More recent estimates of the total number of beef cattle properties in the arid zone are not available but it is certain that the number has increased. For example, it is estimated that in 1969-70 there were 3,609 beef-sheep properties[4] in the pastoral zone /7/. Furthermore, the number of properties in Australia with more than 50 head of cattle has nearly doubled in the last five years[5].

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(3) The boundaries of the pastoral zone of the A.S.I.S. do not coincide exactly with those of the arid zone as given by Perry /8/. Nevertheless, for the purposes of this discussion there is little error in taking estimates for the pastoral zone as applying to the arid zone.

(4) For inclusion in the population list of the sheep industry survey, properties are required to have 200 sheep or more. Properties with at least 50 head of cattle are included in the beef industry population. "Beef-sheep" properties would therefore have at least 50 head of cattle and 200 sheep.

(5) The number of properties eligible for inclusion in the Australian beef cattle industry survey (A.B.C.I.S.) 1962-63 to 1964-65 was 26,134 /3/. The latest estimate (31 March, 1969) of the number of eligible properties for an A.B.C.I.S. now in progress is 51,396. It is unlikely that this increase has taken place entirely in non-arid regions.

Physical Characteristics of Pastoral Properties:

Area: Cattle stations in the arid zone are, in general, much larger than sheep properties mainly because the former are, to a greater extent, situated in less favoured environments. Cattle stations in Central Australia, for example, average about one million acres in size and in arid South-West Queensland the average cattle property is about 780,000 acres. In contrast, the average size of sheep stations in the pastoral zone is 58,000 acres /2/. By comparison with earlier estimates it appears that over the last few years the average size of sheep properties in this zone has increased. This and the slight decrease in the number of sheep properties mentioned earlier can be explained at least in part by the trend to increase property size by amalgamation of properties and the general "swing to beef".

Herd and Flock Sizes: The average herd size in the Alice Springs District ranged from 1,800 head in the drought year 1965-66 to 2,990 in 1969-70 after three relatively good seasons (Reeves and Crellin 1972). In arid South-West Queensland the average cattle station ran 4,275 cattle in association with 7,024 sheep in 1963-64 but only 2,452 cattle and 3,899 sheep after the drought of 1965. The average size of sheep flocks on predominantly sheep properties in this region ranged from 8,099 sheep in 1963-64 to 4,916 in 1966-67.

Sheep properties in the pastoral zone as a whole on average ran about 5,600 sheep (1969-70) in association with 146 cattle. These figures emphasise the tremendous variations in herd and flock sizes that occur in arid environments.

Ownership: The majority of stations in arid Central Australia are owned and managed by resident individuals or family partnerships and only 10% are classified as being company owned. A similar pattern of ownership exists for sheep properties in the pastoral zone but in South-West Queensland, the majority of cattle stations are owned by companies.

Technical Efficiency in Pastoral Production.

Estimates of herd and flock productivity characteristics for selected years in arid and non-arid regions are presented in Table Nos. 1 and 2 respectively. In Table No. 1 the State of Victoria is selected as an "above average" non-arid region. Space does not permit a detailed discussion of the estimates but suffice it to note several points of interest.

- The effect of adverse seasons on productivity estimates for arid regions is very apparent. In the Alice Springs District, for example, the drought which lasted spasmodically for nine years ending in December, 1965, severely reduced brandings and increased mortalities. That herds and flocks

should suffer more from drought in arid than in non-arid regions is not surprising considering the great distances that properties in the arid zone are from major feed centres and the effect this has on limiting the range of drought strategies which can economically be applied by pastoralists in the arid zone.

- Branding rates and mortality rates for herds in arid and non-arid regions are comparable in good seasons. However, because of the higher frequency of adverse seasons in arid areas, cattle herds in these regions have on average over a number of years a much lower productivity.

- As a result, turnoff rates in the arid zone are approximately half those in non-arid regions.

- Wool cuts per head are generally higher in arid regions but wool prices (indicating wool quality) are slightly lower.

Capital Structure.

Total capital values of individual properties in the arid zone are, in general, greater than those in non-arid areas. As at June, 1970, the average sheep property in the pastoral zone was valued at $186,340. Of this, the value of land made up 40%, structural improvements 30% and livestock 21%. Sheep properties in the wheat-sheep zone and high rainfall zone were valued at $127,013 and $123,754 respectively /2/. In these zones, land ccntributes approximately 56-60% to total capital value. Total capital in unit terms for the pastoral zone compared with the high rainfall zone of A.S.I.S. for 1969-70 were:

	Total Capital	
	$/sheep equivalent	$/acre
Pastoral Zone	27.5	3.2
High Rainfall Zone	48.5	97.7

Recent estimates from surveys of the Alice Springs District and South-West Queensland indicate that beef cattle properties in those regions have an average capital value of about $400,000 or about $100-140 per cattle equivalent. In contrast, beef cattle properties in Victoria were valued (in 1965) at about $205,000 on average or $644 per cattle equivalent: land made up nearly 80% of total capital and livestock just over 10%. This contrasts with many cattle stations in the arid zone where land contributes only about 8% and livestock nearly 60% to total capital /5, 9/.

Property Incomes in Arid and Non-Arid Zones.

Estimates derived from several B.A.E. surveys of net farm incomes and rates of return to capital and management for average properties in arid and non-arid regions are presented in Table No. 3. The estimates derived from different surveys are not strictly comparable because of slight differences in the treatment of some items and the individual survey reports should be consulted for details. Nevertheless, these differences are minor and do not unduly affect the broad interpretation of the figures. Two particular points are of interest:

- Given the low rainfall and uncertainty of the arid environment, it is to be expected that net incomes of graziers in the arid zone fluctuate widely between years. It is important to note however that in many cases very large net incomes are earned in good years which more than compensate for quite large losses in drought years. It is clear that net incomes in non-arid areas are much more stable.

- From the data presented one cannot conclude that graziers in the arid zone are any worse off in terms of net farm income or returns to invested capital than graziers in non-arid regions.

Of course net farm income and rate of return on capital are only two of several economic criteria which should be considered in any detailed study of the performance of properties in arid and non-arid regions[6]. Nevertheless some general comments can be made. It is apparent from an examination of B.A.E. survey data that total cost levels and total returns for properties in the arid zone are much larger than their non-arid counterparts. In unit terms, however, costs per sheep or per cattle equivalent tend to be lower in arid than in non-arid regions but so too do returns and to a much greater extent thus reflecting the generally lower productivity of pastoral enterprises in the arid zone. As a result net farm incomes per cattle equivalent are usually lower in arid regions, but because herds and flocks are on average considerably larger, total net farm incomes of arid zone properties are comparable and very often greater than incomes of non-arid properties. They are also, of course, subject to much greater variability.

The Changes and Challenge.

The history of pastoral pursuits in the arid zone has been characterised by an initial period of exploitation, when the potential of the land systems was completely unknown or grossly over-estimated; this has been followed by sporadic periods of severe droughts which have

evoked bitter memories and have taught pastoralists, in general, the art of more conservative management.

Compared with the "pasture revolution" and other technological advances that have taken place in non-arid agriculture since 1945, pastoral production in the arid zone has changed very little. Of most significance has been the advent of road transport which has enabled pastoralists to mobilise stock which might otherwise have died. But in spite of these differences in the rate of technological advance between arid and non-arid regions, pastoralists in the arid zone have been able to match and often exceed the economic performance of graziers in non-arid regions. Part of the reason for this has undoubtedly been the fact that arid zone pastoralists, in general, have been able to maintain properties at a sufficiently large size.

In the future it is unlikely that the type of pastoral activities now being pursued will alter much, and although production from the arid zone may increase slightly, as graziers further develop their properties, it seems certain that total rural production from the arid zone is destined to become an ever decreasing component of total Australian rural output. This is because the potential to increase rural production is so much greater in non-arid than in arid regions.

The challenge to pastoralists is that they will continue to be faced with increasing costs and possibly the prospect of uncertain markets. These will impose risk factors in addition to the uncertainty of the environment. Under these conditions it seems logical to predict that property integration or the ownership of property "chains" linking arid and non-arid areas will become more important. To this end it is likely that individual ownership of properties will give way to large family (or other) partnerships, syndicates or company ownership.

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(6) Space limitations prevent a full account of these aspects. The interested reader is referred to the more detailed study by Waring /10/.

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TABLE NO. 1

SELECTED MEASURES OF BEEF CATTLE HERD PRODUCTIVITY AND MANAGEMENT : BY YEARS

Productivity Measure	Region	Years	Reference	Unit	1962 -63	1963 -64	1964 -65	1965 -66	1966 -67	1967 -68	1968 -69	1969 -70
ARID REGIONS												
Branding[a]	Alice Springs District	1962-65 1966-70	/4/ /9/	%	Ave	44		37	60	65	70	68
	South West Queensland	1962-68	/5/	%	60	57	43	28	41	48	-	-
Mortality[b]	Alice Springs District		op.cit.	%	Ave	12		20	5	4	4	4
	South West Queensland		op. cit.	%	5	5	16	39	4	4	-	-
Turnoff Rate[c]	Alice Springs District		op. cit.	%	Ave	20		24	20	20	31	30
	South West Queensland		op. cit.	%	35	29	32	29	28	28	-	-
Stocking Rate	Alice Springs District		op. cit.	b./sq. m.	Ave	1.7		1.3	1.3	1.6	1.9	2.1.
	South West Queensland			b./sq. m.	5	5	4	3	3	3	-	-
NON ARID REGIONS												
Branding Rate	Victoria	1962-65	/3/	%	75.9	67.6	61.7	-	-	-	-	-
Mortality	Victoria	1962-65	/3/	%	3.3	2.7	3.3	-	-	-	-	-
Turnoff	Victoria	1962-65	/3/	%	60.0	57.0	56.0	-	-	-	-	-

(a) Defined as number of calves branded as a percentage of opening number of cows and heifers over 1 year.
(b) Mortality numbers expressed as a percentage of average annual herd numbers.
(c) Sales expressed as a proportion of average annual herd numbers.

TABLE NO. 2

SELECTED MEASURES OF SHEEP FLOCK PRODUCTIVITY AND MANAGEMENT

BY YEARS

Productivity Measure	Zone	Unit	Years 1967-68	1968-69	1969-70
Wool cut per head	Pastoral	kg	4.5	4.6	4.6
	Wheat Sheep	"	4.1	4.2	4.3
	High Rainfall	"	3.8	4.1	4.2
Wool Price per Kg	Pastoral	cents	90.4	91.1	74.1
	Wheat Sheep	"	88.0	95.2	81.1
	High Rainfall	"	99.9	105.2	90.6
Lambing Percentage	Pastoral	%	62.1	67.7	62.4
	Wheat Sheep	%	73.9	76.6	75.9
	High Rainfall	%	81.2	80.2	83.9
Sheep equivalents per used acre	Pastoral	No.	.11	.12	.12
	Wheat Sheep	No.	.77	.82	.90
	High Rainfall	No.	2.08	2.14	2.25

Source: BAE, "The Australian Sheep Industry Survey : 1967-68 to 1969-70, Preliminary Results", Quarterly Review of Agricultural Economics, Vol. XXIV, No. 4, October, 1971

ESTIMATES OF AVERAGE NET FARM INCOME AND RATE OF RETURN TO CAPITAL AND MANAGEMENT FOR SOME ARID AND NON ARID REGIONS: AUSTRALIA: 1962-63 to 1969-70

Zone/Survey	Reference	Years 1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
ARID ZONE									
Alice Springs District	1962-65 /4/ 1966-70 /9/	-1,151	1,262	-9,364	-19,062	17,166	36,979	48,013	
South West Queensland	/5/								
. cattle properties		45,535	57,047	-28,581	-93,776	5,891	22,106		
. sheep properties		12,506	26,938	8,263	-14,934	3,930	10,843		
Pastoral Zone	ASIS /2/	-	-	6,343	- 4,003	9,366	7,173	15,556	5,715
NON ARID REGIONS									
Wheat Sheep Zone	ASIS	-	-	7,411	4,688	8,501	4,403	9,919	5,271
High Rainfall Zone	ASIS	-	-	5,165	5,480	6,028	2,907	5,763	6,053
Victoria (cattle props)	ABCIS /3/	6,042	8,001	7,488	-	-	-	-	-
		B. Rate of Return to Capital and Management (%)							
ARID ZONE									
Alice Springs District	op. cit.	-1.8	-0.3	-7.0	-8.8	5.8	10.8	12.2	
South West Queensland	op. cit.								
. cattle properties	op. cit.	10.5	12.0	-6.7	-24.9	1,0	4.9		
. sheep properties	op. cit.	6.7	14.5	3.9	-10.7	1.3	5.7		
Pastoral Zones	ASIS	-	-	6.5	neg.	11.1	5.4	13.3	3.7
NON ARID REGIONS									
Wheat Sheep Zone	ASIS			16.8	8.4	18.2	4.7	15.9	6.1
High Rainfall Zone	ASIS			11.6	11.5	13.5	2.2	8.8	8.4
Victoria (cattle props)	ABCIS	2.2	3.1	2.8	-	-	-	-	-

CLOSING COMMENTS AT THE AUSTRALIAN WATER RESEARCH FOUNDATIONS SYMPOSIUM ON ARID LANDS, ADELAIDE, SOUTH AUSTRALIA.

Thadis W. Box

I think if I had used by better judgment I would simply have read the paper I prepared and thanked you for your attention and caught the first plane home; but since Yanks have not been known for their good judgment, particularly in the area of international relationships, I am going to lay myself open to all sorts of criticism. My intentions are to evaluate the conference as I see it.

One of the first points I would like to make is that Australia's arid lands are in better condition than most such areas of the world. This point was made in Mr. Perry's paper and I would like to underscore it. There are some areas which are in a degraded condition and which need some sort of attention, but on the other hand there are many areas here that are not in poor condition.

One special consideration is the reaction of Australian vegetation to exotic animals. Certainly all deserts have responded to the introduction of animals not native to them including livestock. When a plant community has evolved under grazing by certain biological organisms and some new animal is introduced that has different food habits and different diets, the vegetation is bound to respond and change - and change rather drastically.

Australia, due to the fact that it didn't have large browsing animals such as other large deserts of the world, has some peculiar characteristics and peculiar responses to exotic animals. Several people have mentioned the feral animal in this meeting - certainly rabbits are an important factor in the arid zones of Australia. Any feral animal that is uncontrolled will cause range deterioration - donkeys, camels, goats and any number of things. But, here I want to underscore a point made by Mr. Perry in the very first paper. Most of these ecosystems in Australia have been altered by man and his animals. Removal of any use to which they are being put now will not mean that they will return to their original condition. In fact they probably will not and some sort of management is going to be necessary to restore them. Someone has to decide what is wanted from these lands and then work to reach and maintain the condition desired.

Other restrictions that I mentioned in my paper and talked about the other night are social and political constraints. Several people have mentioned them already. Most Australians live in the humid regions. That is where the political power is and the use of the land in the Centre is determined by these people not directly associated with the arid zone.

I think that you can expect most people in Australia to have a humid zone mentality. I was a little bit surprised, and I guess a little bit shocked, that some humid zone thinking has shown up at this conference. Constant reference to the dry inhospitable centre, drawing of a National Park along political boundaries rather than

natural boundaries, and a statement from the audience that you can scatter a hundredweight of super across the country and reclaim it are examples. With speakers at this conference saying that the arid zone is an inhospitable country unfit for human habitation, what can you expect from the layman?

That Australia's arid zone is a harsh and inhospitable country is a myth. These are the easiest deserts I have ever worked in. If you have a positive traction differential on your automobile you can drive over most of it without a four-wheel drive vehicle. There are no big mountains. There are, of course, some big ranges but you don't really have to get on a horse or even in a four-wheel drive to see most of it. This is easy, extremely easy, country. I think it was the first explorers who brought back these ideas of a country inhospitable and difficult to live in. People believed it and many still have that image of the centre.

Another aspect of the conference that concerns me was that the whole first day of this symposium was devoted to conservation of the arid centre. With the exception of a brief mention by Bob Lange that the official attitude toward the Aboriginal was to get him off the land as quickly as possible, these people were not mentioned except in a question from the audience. The people who live in the arid zone were not even considered or mentioned until Professor MacFarlane raised the issue. I wrote in my notes, "You have reserves for Aboriginals and you are going to create some sort of National Parks, I would suggest that you create some reserves for pastoralists - European types". This is another example of people from humid areas making plans for the arid region without considering those who have long lived on the land.

The other constraints which I mentioned were economic, but I dare not talk about them with Keith Campbell sitting out front. I am going to leave this portion to him with the exception of mentioning that at least two of the speakers, Mr.Hancock and Mr. Parkin, feel strongly that if economics justifies doing anything you do it. At this point they are probably right. The world does operate on economic laws, but I would hope that we would also use some ecological constraints as well. Any project should be done in a manner which is both economically and ecologically feasible.

Let's back off a little now and take a look at some more comments of people here at the conference. I have been criticized by several people during tea-time about my approach to population pressures in a public address the other night. I am still going to stand by my guns that what happens in the Australian Arid Zone is mainly a function of world population. Certainly Australia may be the last continent to feel the pressure of more human beings. It may also be one that is not as directly affected by population pressures as our American Arid Zone

or Africa, but I have tried to make the point in the formal paper that attitudes to arid zones depend on people outside of them, and if you look at the whole world as an ecosystem the Australian Arid Zone has to be influenced by the people in Europe, Africa, United States, etc. The U.S. has a change in its meat import quotas and I would suggest that very soon there will be a marked increase in the beef coming into America. The Australian Arid Zone will be a major place furnishing the increase.

If we look at the future of Australia's Arid Zone the use that will continue for the longest period of time will be pastoral production - production of animal protein. As the human population grows and we eat more grain, red meat will become a luxury item produced in those areas which are too cold, too hot, too high, or too dry for crop production. Australia's Arid Zone is one of those areas. I think that we are already seeing some rather subtle changes in pastoral production here. The shift from sheep to cattle has already taken place in the United States, and I think that if the wool prices give the pastoralist problems, we will see more of this shift in Australia. Several questions were asked in the papers over the past few days as to what is going to happen with this change. We can make some predictions based on what has happened in America, East Africa, etc. but I don't think we will really know until it happens. The consequences of this change offers a major area for research. Not only the biological changes involved, but the sociological changes as well need to be predicted and understood.

As the demand for meat products increases over the world, I think you will see some major changes in the Australian meat production industry. We can look forward to much more efficiency. If you examine the turn off rates in the Arid Zone, for example, you find figures quoted from 9% to 19% annual off-take depending on the areas. These figures are not any better than the Masai in East Africa. That is about the same kind of turn off that you get from these pastoral nomads that Victor McFarlane showed in his pictures. There is certainly room for a marked increase in efficiency, and it is only a matter of the economic situation forcing changes. We will see cattle marketed at an earlier age and more breeding animals in the population. No one can expect a very big turn off if only 25% of your basic herd is breeders. The trend will be for more and more shifts to younger cattle, greater turn off and greater efficiency. Inputs will increase. These inputs may not be economically feasible at the present time, but only a very small shift in the world market may bring about many changes in the Australian cattle industry.

Another thing we can look forward to is a worldwide change in the kinds of animals used on rangelands. I've taken a lot of kidding the last couple of days about my Texas goats, but I believe goats are an animal of the future. Fortunately, you have a real expert on animals here in Adelaide. Victor McFarlane at Waite Institute knows far more about efficiency of animals than I will ever know. We can look

forward to his contributions. Somebody else may look at the great amount of genetic diversity that is available to the animal industry and develop new breeds and species. It may not be goats that are tomorrows animals, I use goats for shock effect. It may be some other breeds of cattle, other breeds of sheep, but tomorrows range animal will not be the same as those used widely today. Sheep alone have roughly 150 breeds scattered over the world with which most European people have not made contact. The fat-tailed and fat-rumped varieties may offer improvement in some areas.

Changes will come very slowly. It may take a sociological revolution to get people to accept some of these meats that can be produced more efficiently. Tim Ealey mentioned in his talk that Euros produce more protein than sheep. This statement struck a note with me because I was raised in an area where we made good use of wildlife. We produced deer rather than euros and kangaroos. Many times more economic gain came from the management of deer than from the livestock on the property. We sold hunting privileges, but they could be sold for meat.

Whenever animals with different diets, native or exotic, live together, more efficient use of the vegetative resource is made. Let me be quick to caution that it takes more management and economic inputs to run more than one class of animals. A piece of country can be ruined faster if you have got 4 or 5 different kinds of animals eating different things than if only one species is grazing. There is a potential for increased gain with common use, but there is also a potential for increased destruction.

Another hope for increased production of arid lands is irrigation - irrigated agriculture. Mr. Hancock was very optimistic in his presentation. He suggested developing underground water supplies in many places in arid Australia. Certainly, there are very many underground reservoirs in Australia, but they vary in quality and quantity and rate of recharge. Personally, I don't see any large scheme developing at present for using these resources. Some will develop slowly as the need occurs. The first big change in production from the arid zone will be the increased supplies of meat products, probably beef. Intensive ways of raising beef may call for supplemental feeding as an input. It may be easier to grow the supplement for breeders on a small irrigated plot rather than truck in the feed from the humid zone. There will be a gradual development of thesespecial crop areas to serve the livestock industry.

Special development of high value crops such as melon or oranges for the Singapore market may occur. Israeli oranges fill Singapore markets when these markets are in your own back door. There may be some opportunity for growing specialty crops for specialty markets, but I see no real call for big development in Australia based on underground water.

I agree with Mr. Hancock in that I do not see very much opportunity for surface water development in rivers and big dams. Mr. Reid mentioned the marked increase in productivity associated with range pitting and I think there is real opportunity to utilise rainfall more efficiently with small pittings and catchments. Ray Perry's first paper mentioned mulga communities and the runoff/runon situation where two thirds of the land is used to catch water to grow vegetation on one third. A similar system of dry land farming developed by Johnston in Bushland, Texas, uses this principle. His scheme of farming is to use two thirds of his farm to catch water, one third of it to grow plants. It is simply a system of modifying, with modern technology, many of the flash flood irrigation systems that have been used in the Middle East and Africa for many many years. At New Mexico State University, Herbel has used essentially the same techniques on rangelands. He uses a small watershed that is left denuded in the desert to run water on to a narrow strip to grow forage. If irrigation develops in Australia's centre it won't be the big crops and large farms, but very simple flash flood runon types of irrigation schemes.

Another item that has been continually mentioned during this conference has been the booming recreation business and the recreation potential of Australia's arid zones. There are at least two types of tourists that we deal with in the arid lands of the United States. One type is what I call the trophy hunter who gets on the fastest plane or the best road and goes to see a tourist attraction. He checks it off his list, takes a picture of it and he may not even stay long enough to play a round of golf before he is off to see something else. He sees them as fast as he can, taking slides to show and bore someone with back home. This type of tourist is in Australia now. You can do him and yourself a favour by sitting him down in an air-conditioned building and show him slides without having him mess up the outback. He does bring money into the area. The money goes largely to people associated with the carriers, hotels, etc. as represented by Mr. Gluyas. The income will not be particularly great for the local people.

We are finding in the States that with the advent of large self-contained caravans, even the local communities are not benefiting as much as before. The tourist comes in completely equipped with bed, food, booze - everything except a little petrol - and leaves again. Thus, this trophy-hunting tourism may not be such a boon to the arid lands as is sometimes thought. Mr. Gluyas in his talk seemed to think that governments should develop tourist facilities. I maintain that this trophy-hunting facility is best furnished by private enterprise because they are the ones who will benefit directly from it.

The other type of tourist or recreationist that we are encountering in the States is the type who wants to get away from it all. He may not be anti-social, but he wants to get out and spend some time

out of contact with other people. There are thousands of back-packers going into the wilderness with minimum equipment. They have a somewhat greater impact on the local community because they stay around a bit longer. One thing that has struck me as particularly lacking in the Australian tourist industry is a lack of interpretation of natural phenomena. You can go to a beautiful Botanic garden, of which there are many in this country, and the only interpretation is the Latin names of trees. There are not enough signs, guided tours, etc. I can visualise the road from here to Alice Springs being a real good educational experience if it were properly developed with interpretative signs - not just a long, dry track, but an educational experience. I think that this is a legitimate area of responsibility for government. It was mentioned in a comment from the floor that tourism not only represents a vast potential for economic gain, but a vast potential for ugliness. I would underscore this. People are a lot more difficult to handle than sheep. They may also be more profitable than sheep. We have a saying down in Texas that one tourist is equal to 20 sheep and a darn sight easier to fleece. This may not be true if they are not properly handled.

Another thing lacking is interpretation of your history. Camels have been mentioned many times here from the point of view of producing milk or meat, but I would maintain that the camel has the potential to be for Australia what the cowboy has been for America. Many people think of America as a nation of cowboys, but the cowboy era was only about 20 years long - from the end of the Civil War to near the turn of the century. Someone has figured out that we make more money in one year on taxes on cowboy apparel than the value of all the cattle driven up the trails during this 20 year period. I am not sure that this is a realistic statistic, but the fact remains that we have capitalised on this cowboy image. Nowhere else in the world has the camel had a more interesting impact on the history of a nation. He is a true piece of Australia even though he came from elsewhere. This is the only place I know where he was put in great teams of 20 animals pulling drays, etc. This is a peculiar use of this beast, peculiar to Australia, and it is a use I think should be exploited by the tourist industry.

The other thing that worries me about tourism and recreation is the impact of all-terrain vehicles on the landscape. If you think herds of sheep and cattle are destructive, wait until you see the effect of people running four-wheel drive vehicles over desert vegetation. In Utah we can still see the wagon tracks that pioneer parties made crossing the desert in the middle 18 hundreds. Nowadays, when we run a Toyota, Land Rover, or a trail bike over the desert we are making ugly scars which will be there much longer than we would like to think.

There is another potential for arid lands that I put in my paper, but didn't intend to mention because it scares the wits out of me. Bob Lange, however, has already mentioned it so I will discuss it too.

This is the possibility of using the arid land as a waste disposal area. I would hate to see the arid lands of the world become the rubbish heaps for the humid regions, but there is some support for this use particularly from people who live in the humid regions and want to get rid of something ugly or smelly. Now that more and more restrictions are being put on the use of the sea for waste disposal I live in fear of what may happen to many of the arid regions of the world.

The other potential that is not really peculiar to arid lands but was discussed at this conference is mining. Minerals are where you find them and there are a lot of minerals in arid lands. It is the quest for minerals that has developed many of the arid lands in the first place. There is a train of thought going through the minds of mining people throughout the world. They seem very defensive and wish to convince us that mining is a necessary part of the world about us, but I don't know that we can convince people that digging holes in the ground makes for a more beautiful landscape.

I would like to finish on the development needs. The first priority item is to get the arid lands in a high priority area with those people in power. I was really impressed with Premier Dunstan's speech the other day. He said the right things, I think, but I am concerned with the attitude of the general public as with that of our leaders.

This whole conservation movement can be a boon to us or it can be a millstone around our neck. I was somewhat surprised at some of the statements that came out of the conference here. For instance, there is a real good case for maintaining genetic diversity and protecting endangered species, but when Tim Ealey talks about magnificent grizzlies and miserable Mexicans I really get ruffled because I am on the side of the Mexicans. I think this sort of attitude is really setting back the conservation movement.

The second high priority item that I see is more research to understand the arid lands. This means more resource surveys, understanding of ecosystem dynamics, more research into socio-economic factors.

The third need is for more trained people to implement this research. This has been touched on by Bob Lange, but at one place I must take issue with him. I think academics have a real responsibility for placing the people they train and for guiding government agencies to use these people once they are produced. One of the things I take very great pride in is that over half the land in the United States is managed by Utah State University graduates. The heads of the United States Forest Service, the Bureau of Land Management, the

Bureau of Reclamation - run right down the list - come from our school. Agencies need people trained in resource management. I suggest that similar training must be available here if you are going to develop your arid lands.

Well, my time is up. I think Australia's arid regions have a great future and I expect I have laid myself open to a great many criticisms which I hope to hear in the next hour.

THE FUTURE OF AUSTRALIA'S ARID LANDS

Keith Campbell

Professor of Agricultural Economics
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At the closing session of a conference it is salutary, as well as useful, to look back and ask whether the conference has achieved the objectives for which it was organised. In the case of the present symposium, the objectives were laid out fairly explicitly by the organising committee. They were three in number :

(1) to have a critical and authoritative look at the water resources of the dry regions of Australia and the challenges and opportunities for balanced development of the arid lands;

(2) to examine important environmental matters such as the conservation of the fauna and flora of the dry areas, the potential for tourism and natural resources; and

(3) to achieve some informed opinion on the realistic physical and economic development of arid Australia.

In this final paper I propose to concentrate on the last stated objective, namely the realistic development of the arid lands. However, I shall also refer to some of the contributions made towards the other objectives of the symposium.

Development as a Goal in Arid Areas

One of the dominant motivations in Australian national life from the beginning appears to have been a desire to develop the continent. This has been more than a desire on the part of private individuals to grasp economic opportunities, or to use the American vernacular "to make a fast buck". Community leaders, politicians and governments have been fired by a development ethos which in the early days of settlement was manifest in the measures to push back the frontiers of settlement. There were, it is true, occasional attempts to restrain settlement, but usually it was only by bitter experience that people came to accept the limits of feasible production. The early attempts to confine New South Wales settlement to the original nineteen countries and the expansion and later abandonment of wheat production beyond Goyder's line in this state are a good illustration of this phenomenon.

Why, it must be asked, is it still considered necessary to further develop the arid lands for rural purposes and why is it necessary that the development of these areas be "balanced development", whatever that may mean? As previous speakers have pointed out, the economic productivity of the pastoral industries in the arid lands is very low as compared with those in more favoured parts of the continent.

Why not, at least for the time being, give up attempts to struggle with the most inhospitable of environments and concentrate on areas where the economic returns to investment are greater and more assured? As Macfarlane said in his paper, "there is no critical necessity for human use of the 5 million km^2 of arid country".

There are other countries (such as Israel) which are far less well-endowed than Australia and which are compelled to do something to make their arid lands productive, even at great cost, in order that they may have a viable economy. But there appears to be no logical reason why we should outlay investment in an effort to improve the productivity of our arid lands. If we succeed in containing world population growth by the turn of the century through the efforts of the protagonists of "zero population growth" or otherwise, it may not even prove necessary in the longer run to consider means of taking advantage of arid lands which currently cannot be economically used for food and fibre production. If, in a world context, it is necessary later to enlarge the land base despite the increasing productivity of existing agricultural land, it is possible that the equatorial lands may be more amenable to economic development than the deserts of the temperate latitudes. I believe that we should delay any efforts at intensive development of arid lands for food production until there is a demonstrable need for more food from such areas. That means in practice that either food prices rise to such high levels, or technological breakthroughs reduce the present prohibitive costs to such a level, that production becomes an economic proposition.

Of course, it may be argued that if there is a possibility of this eventuality arising within three decades, it is not too early to begin scientific research and feasibility studies to that future governments may be better equipped to cope with the situation when it arises. Even this proposition is questionable, because engineering technology itself is changing and, in the nature of the case, the advances are likely to come from overseas because other nations are more able to commit resources to the costly research necessary. When technology is likely to change, it is wasteful to make plans in terms of contemporary know-how. As Hancock has said, methods of nuclear fracturing may come into more widespread use. In addition, other peaceful applications of nuclear energy may become feasible and more economic methods of desalination may be discovered, leading to drastic changes in the feasibility of water supply and irrigation scheme.

There is one instance where intensive agricultural production may prove feasible in the arid areas under present conditions. That is in the supply of fresh vegetables to isolated mining towns and the like. Given adequate supplies of water at reasonable cost it is possible to produce welcome supplies of fresh agricultural produce for local use. The vegetable production which was undertaken for many years at the aged men's hostel at Alice Springs is a case

in point. In the early sixties there was even talk of supplying Adelaide with vegetables in winter time; but quarantine regulations of doubtful validity proved a major obstacle. With the advances in cold storage and quick-freezing which have occurred in the last decade or so, the case for local production of fruit and vegetables of the kind just described has become less attractive.

It seems to have been fairly well agreed by the speakers that the most likely major forms of economic activity in the arid zone in the immediate future are pastoral pursuits, tourism and mining. I shall discuss each of these in turn.

Should Pastoral Holdings be Replaced with National Parks?

The pastoral industries were the earliest form of occupation. Mr. Cashmore seems to believe that governments should have been stricter in policeing the limits of settlement and that even now it would be better to withdraw the present pastoral leases, compensate the occupiers and put the land into public reserves. I am not clear why, if this is to be done, such lands have to be dedicated as national parks. Possible dedication as a park implies a more permanent commitment on the part of the Government to maintain the lands as part of the public domain, but this seems a curious conception of the purpose of a park. In any case, as indicated earlier, the future growth of population may necessitate some reassessment of the use of arid lands in the years to come.

There seems to have been a conflict of opinion among the speakers at the symposium about the effect of pastoral occupation. Cashmore and others have been saying that further pastoral use of the lands will mean a continuing deterioration in the flora and fauna of the areas concerned. Perry, in contrast, while admitting the subjectivity of assessments of the condition of the ecosystems, expressed the view that "the main changes occurred within a decade or two of settlement..... that since then changes have been relatively slight" and that "most of the grazing lands have...come to a reasonably stable new equilibrium".

For my own part, I find the latter assessment to be the more plausible. It is worth remembering that even in more favourable climes, it is often impossible economically to maintain the productivity of occupied lands at the same level as they were before settlement. The prairie lands of North America and the red basaltic soils of the North Coast of New South Wales would be two cases in point. In short, rural occupation for productive purposes more often than not implies the establishment of a new ecological equilibrium representing a level of productivity, sometimes lower and sometimes higher than the level existing before settlement.

There are those who use the state of the original virgin lands as their benchmark for assessments of the present condition or trend in the condition of an ecosystem and hold any departure from this state to be less than desirable. In my view these people are misguided. But here we get into the area of beliefs and values rather than of scientific objectivity. The values individuals hold cannot be adjudged right or wrong according to scientific criteria. Very often, one can only agree to differ. Personally, I cannot see that the world would be a better place if the New Zealand moas had not become extinct, or that it is worthwhile spending time and money attempting to restore current rangelands to their pristine state. I believe in conservation, but I cannot go along with the more extreme manifestations of the creed. Accordingly, I think the question of resuming badly despoiled areas or taking steps to prevent further deterioration has to be distinguished from that of making frantic endeavours to get the said lands back to their former state.

Controls on Pastoral Management

On the question of the management of the arid rangelands, assuming they are not to be absorbed into national parks, I find myself very much in sympathy with the views expressed by Reid. Given the diversity of natural flora and the very uneven impact of rainfall, it would be imprudent for a central authority to lay down inflexible rules of land use.[1] Successful pastoral management in an environment as uncertain as that of northern South Australia and Central Australia must be adaptive, utilising the skills acquired from past experience. If the Government were prepared to use public money to achieve detailed supervision of range management on individual stations, the argument of the scientists for supervision might be plausible, even if open to question. But given the present administrative resources, reliance on the good judgment of pastoralists is essential.

To this end, restraints on adaptability should be minimised and measures to facilitate flexibility extended. As illustration of the first, I would cite conditions in leases setting maximum and, worse, minimum stocking rates for holdings. On the positive side, the programme of constructing beef roads has facilitated the movement of stock in adverse seasons.

These aids to flexible management need to be distinguished from public assistance designed to make production economic in circumstances where unaided it would be out of the question. I believe that public subsidies designed to offset the economic disadvantages of areas of low economic productivity are unjustified and lead to serious misallocation of national resources. To give a

1. See Keith Campbell, "Problems of Adaptation of Pastoral Businesses in the Arid Zone," Australian Journal of Agricultural Economics, Vol. 10, No. 1 (June 1966), pp. 14-26.

specific illustration, banks could be more flexible in their lending and repayment policies and not attempt to apply to pastoral enterprises in uncertain arid areas the same lending policies as they have developed for more humid parts of the continent. At the same time, special low interest rates should not apply to loans to pastoral firms in arid areas, and special low freight rates should not apply in such regions except in periods of seasonal adversity.

Land Tenure in the Arid Zone

I am inclined to challenge Heathcote's contention that, in general, the aim of Australian land settlement policy has been the alienation of the land. This may have been true of policies in the early years of settlement, but I believe this view has long since been superseded. With some 90 per cent of the rural lands still in the hands of the Crown, Australia probably has the highest proportion of publicly-owned land outside the centrally-planned economies.

The economic case for private ownership revolves around the fact that such a form of tenure is more conducive to the encouragement of investment and of management motivated by a desire to ensure the long-term viability of the farm. Somewhat similar arguments are made for long-term leases, but the force of these incentives rapidly diminishes as the period of the lease nears its end.

The case for leasehold arrangements on the other hand rests on three main arguments. First, under a rental arrangement, the farm operator is not required to tie up so much of his limited capital in real estate and is thus able to apply it to more productive purposes. In the second place, the existence of a crown lease enables the government to exercise more control of land use whether in the direction of requiring a certain rate of development or of assuring conformity with approved conservation practices. Finally, insofar as the myth of the inevitability of an increasing intensity of land use persists, crown leases do permit the government to reassess the size of holdings at periodic intervals.

These arguments in favour of leasehold are not particularly pertinent to lands administration in arid areas. The first argument is of less significance in arid Australia than elsewhere because land there has such low, if not zero value. As far as the second is concerned, it is doubtful, as pointed out earlier, whether centralised control over range management is either desirable or effective. As for the third, there is no imminent prospect of more intensive use of the arid pastoral lands. If some unforeseen breakthrough in technology did occur, it would still be open to the Government to resume the lands in question and the compensation payable would be unlikely to be very different to that payable if a leasehold system

prevailed. In short, one can make a case for alienation of the grounds that it might encourage greater investment designed to conserve the vegetation and ensure greater stability of production in adverse seasons.

The Market Outlook for Pastoral Products

Though in times past, cattlemen have passed through periods of severe economic stress arising from low beef prices, the current long-term market outlook for meat seems assured. The demand for animal protein is likely to increase not only in existing markets such as the United States, but also in developing countries as their populations become more affluent. This is not to say that the appropriate policy for the arid zone should be that of producing finished animals. There are indications that it is more appropriate to follow the policy of the south-western states of the United States and breed young cattle which may subsequently be finished in more favoured areas.

Here I must take issue with Macfarlane's remarks about possible alternative livestock enterprises for the arid lands. There appears to be some confusion as to what determines the relative economic productivity and profitability of different enterprises. First, it is important to recognise that physical productivity is very different from economic productivity. It may be possible to achieve extraordinarily high yields of, say, corn in some obscure part of New Guinea, but if there is no local demand for it or if costs of transportation to market are exhorbitant, such land may have zero economic productivity. To be more specific, the efficiency of feed conversion, the yields of nutrients per acre, the rate of water turnover and similar physiological characteristics are some of the factors that determine profitability of animal enterprises. But profitability is determined as much by considerations of market demand as by conditions of supply.

In this context, it is difficult to see any place for Macfarlane's exotic species, however, well they may be adapted to the arid zone, so long as consumers prefer beef steak to camel or goat steak. Moreover, I doubt whether taxpayers would like to see Treasury funds spent fruitlessly on promotion designed to convince the Australian public that camel meat is preferable to sirloin or lamb chops.

Attempts to utilise feed conversion rates or calorific output per acre as criteria for national food and agricultural policy, at this stage in world history are, in my judgment, examples of the misapplication of science. The only hope I see for the possible economic development of meat production from the exotic species mentioned by Macfarlane would be if payable export markets could be developed in overseas countries the inhabitants of which are

accustomed to consuming the meats concerned. Such exports could take place in the form of meat or in the form of live animals, such as the shipments of live sheep currently taking place to the countries around the Persian Gulf.

These comments in no way detract from Macfarlane's case for modification of current quarantine structures to permit the importation of genes which will enable us to secure strains of cattle and sheep better adapted to the arid environment and perhaps better adapted to the changed ratio of sheep meat to wool prices that may well apply in the future. We may have to change our attitude to the joint production of sheepmeat and wool to one more analogous to that applying to beef and hides. In short, we may have to produce sheep primarily for their meat and regard wool as a relatively unimportant by-product.

The case for new animal industries in the arid zone assumes a different complexion if one moves beyond meat production for human consumption. The magnitude of the demand for animal protein for pets in the affluent countries is quite staggering. In Australia in 1970-71, for instance, the production of canned pet food alone amounted to 77,366 tons. Economic production of cheap protein from some of the animals mentioned by Macfarlane may enable more sheep meat and beef to be diverted to human consumption at home and abroad. This problem is likely to become of greater importance to the extent that the world's population increases and the demand for and price of the conventional meats of the Western world rise.

The Tourist Industry

The two other major forms of economic activity in the arid zone - tourism and mineral production - both have the common feature that they represent the exploitation of relevant assets existing in the region. It is simply a matter of discovering them and exploiting them. If there are no exploitable assets little can be done about it unless, of course, the community is prepared to build an opera house of the Sydney variety in Alice Springs.

Recent developments in tourism in the Northern Territory confirm one of my more successful excursions into prophesy. In a paper to a conference in Darwin in 1961, called to discuss possibilities for the development of North Australia, I urged the diversion of resources to tourist development rather than the then popular agricultural development. This advice was based on the premise that the investments most likely to be conducive to sustained economic growth in a region are those in goods and services the demand for which is highly responsive to long-term rises in income per head. I quote from the paper in question.

> At the present stage of the development of the Northern Territory and in the absence of opportunities for the development of secondary industries, the choices on this criterion are not too wide. Outside the field of primary industry, the major possibility that comes to mind is tourist facilities. Absurd as it may seem on the surface, investment of public funds that will stimulate the output of recreational services and increase the number of tourists coming into the region would pay dividends in the economic growth that would be set in motion.[2]

As Hyde reported to this conference, the tourist industry in the Northern Territory in 1969-70 was growing at the rate of 12 per cent per annum, and bringing in an income of $18 million to the Territory. (The gross value of beef production in the Territory in the same year was only $21 million.) There is no reason why this rate of growth should not be maintained, provided that satisfactory transportation, accommodation and recreational facilities are provided, as Gluyas has emphasised. Irrational though it be that Americans accept Sydney Harbour and Ayers Rock as the epitome of Australia, we have to cater to this irrationality if we want economic growth in the arid centre of the continent. But it needs to be remembered that the typical international and indeed Australian tourist wants to experience comfort rather than the rigours which the pioneers endured.

In 1965 a party of scientists made an excursion to Ayers Rock by tourist bus and stopped en route at a station homestead for afternoon tea, the proprietor of the station having decided that catering for tourists was more lucrative than cattle-raising in the middle of the drought. Among the party was an enthusiastic chemist whose normal activity was the analysis of water and who took his kit along and continued his activities while on tour. His analysis of the water used to make the cup of tea that afternoon showed that it contained the equivalent of a strong dose of Epsom salts. This is not the stuff of which an expanding tourist industry is made. Good water supplies are essential as a minimum.

The Mining Industry

The more rapid rate of discovery of oil and gas and mineral deposits in the arid zone in the last decade has greatly enhanced the income prospects of the region. Given the resources currently devoted to exploration activities it is possible that the future may be even brighter than the present. But the exploitation of oil and minerals has a much more limited impact on the economy of the region than the tourist industry especially when the local activities are purely extractive and the processing is done elsewhere. In this case, the

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[2]Keith Campbell, "Economic Aspects of Development in the Northern Territory " Northern Territory Scientific Liaison Conference 1961, Conference Papers Voo. I No. 57, p.5.

boost to secondary employment in ancillary service industries in the region is much less than in the case of the tourist industry. The typical set-up is the isolated self-contained company-owned mining town of the type described by Young in his paper on Windarra. Such development is usually once-and-for-all growth rather than a catalyst for sustained growth.

Empty Space is an Asset.

In discussing the prospects for future development in the arid lands, it is important to recognise their limitations and their advantages. A region whose economic activities are largely limited to the products of mining and pastoral pursuits is virtually condemned to a slow rate of growth. The prospect are that such regions will increasingly lag behind other regions in their rate of growth. Such has been the experience of the western interior of the United States and there is little reason to expect the experience of arid Australia will be very different.

On the other hand, given the mounting population pressure in much of the world and the increasing problems of environmental health stemming partly from expanding technology and partly from increasing affluence, there are decided advantages from a national standpoint in having empty spaces. In future, a desire to preserve voids may replace the former compulsion to fill them. Since the Second World War the less occupied parts of the world surface have proved ideal for testing rockets, for experimental nuclear blasts and as sites for nuclear plants and missile-launching sites.

On a more humanitarian plane, large empty spaces around industrial areas do facilitate the natural dispersion of atmospheric pollution. For this reason Australia is likely to have less problems with atmospheric pollution than most other advanced countries. Because of this some of the imported prophets of ecological doom would do well to study some local geography before they preach to Australians. Recently, the arid regions of the Australian continent have been advocated as the ideal location of corridors for supersonic aircraft travelling from Europe to the eastern seaboard. Perhaps we need to look more closely at the arid lands in a national context rather than simply in regional terms.

Despite what has been said at the conference about the desirability of local control as against control from outside the region, it has to be accepted that insofar as the inhabitants of the humid areas are taxed to support services in the more sparsley populated arid areas, they are going to demand some say in how the money is spent. The use and control of the arid lands is a national problem and needs to be treated as such.

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