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Rural (non-irrigation) water supplies in Western Australia : a perspective to the year 2000

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Rural Water Supplies in Western Australia

A perspective to the year 2000

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Contents

Figures & Tables

1. Physical And Climatic Description

1.1 Agricultural and Pastoral Areas

1.1.1 Agricultural areas

The agricultural areas lie between latitudes 28°S and 35°S; and receive an annual average rainfall between 625 mm and 275 mm. The climate is Mediterranean, with cool, wet winters and hot, dry summers. Eighty per cent. of the rainfall falls in the May to October period. Annual rainfall is variable; e.g. Bencubbin in the north—eastern wheatbelt has an average annual rainfall of 300 nun; but in 10 per cent. of years the annual rainfall is less than 210 mm and in 10 per cent. of years it is more than 450 nun.

Rainfall intensities are low and rainfall per wet day is also low. Evaporation (Class A pan) ranges from 1,200 nun per annum on the south coast to 3,000 mm per annum in the northern wheatbelt.

Topography is subdued. Very few streams contain potable, or even livestock quality water, and very few of the streams contain permanent water. Under many valleys the groundwater is saline and the water table in these valleys is often within 4 m of the soil surface, thus limiting depth of dams which are a common source of water.

Surface soils are often either sandy and/or gravelly (pisolitic ironstone) and have high infiltration rates.

Runoff from natural catchments (covered with original vegetation, or with agricultural crops or pastures) is infrequent and of small amount.

1.1.2 Pastoral areas

The Western Australian pastoral areas are of great extent and are conveniently described as two regions which are physically and climatically distinct.

The Kimberley region is in the extreme north of Western Australia, and lies north of latitude 20°S. The climate is dry savannah. Annual average rainfall ranges from 300 to 1,250 mm, and is moderately variable between years. Rainfall intensities are generally high and rainfall incidence is mostly in the December—March period.

Evaporation (Class A pan) ranges from 2,200 to 3,500 mm per annum. Topography is rugged and access by vehicle is often difficult.

Permanent river pools constitute a commonly used water resource. Runoff from rangelands is rapid and plentiful, and the area is susceptible to soil erosion.

The Pilbara, Gascoyne, Murchison and Goldfields regions (see Figure 1 attached) have average annual rainfalls in the range 160 mm to 300 mm, with most of the area receiving less than 250 mm. Rainfall variability is extreme. In the Pilbara effective rain falls mainly in the summer (January and March). South of the Pilbara, most effective rain falls in winter although in some areas very heavy falls of rain are received in summer associated with more northerly cyclonic disturbances.

Fig. 1. Map Showing Major Agricultural and Pastoral Regions of Western Australia.

Rainfall intensities during cyclonic storms can be high, although most rains in the cooler months (May to September) are of low intensity.

Evaporation (Class A pan) is extreme, ranging from 2,000 mm per annum on the Nullarbor coast to greater than 4,000 nun per annum in the Pilbara.

Topography is generally subdued, although some rugged range country exists.

River systems are extensive throughout the area, though they are ephemeral. Perennial pools can be found infrequently in the main water courses. The eastern Murchison and Goldfields have a well—developed internal drainage system based on large saline lakes and playas. Groundwater within these trunk drainages are highly saline and follow the path of ancient trunk drainages.

1.2 Livestock Populations

Livestock populations in Western Australia at March 31, 1981 were as follows:-

	Total livestock Western Australia	Agricultural areas	Pastoral areas
	(in millions)		
Sheep	30.8	29.0	1.8
Cattle	2.0	1.1	0.9
Pigs	0.3	0.3	0

1.3 Water Demand And Water Quality

Throughout the agricultural and pastoral areas water is required in relatively small but continuous supply for livestock (sheep, cattle or pigs) and for homestead use, at frequent spacings throughout the whole alienated area. The water demand is composed of about 70 per cent, for livestock and 30 per cent for homestead use. In the agricultural areas, water is required on average at about 2 kilolitres per hectare per year and is required at supply points serving area units of about 100 ha.

In the pastoral areas, water is generally required in smaller amounts per hectare on an annual basis. Water points are rarely found at wider spacings than 5 km in the pastoral areas. Water demand in the pastoral areas is very much more variable depending upon local stocking rate and the kinds and classes of animals carried.

It should be noted that water for culinary and washing purposes in homesteads, which represents less than 25 per cent, of all rural and pastoral use, should he of high quality (i.e. low salinity and low bacterial content). Roof runoff is commonly used for these specific purposes. Water for livestock need not meet such high quality specifications.

It must be emphasised that because people constitute an integral part of the agricultural and pastoral industry, along with livestock, the water supply technology used must cater for both people and livestock. The water requirements for people and livestock differ in quality, distribution, and amount; although both requirements are for relatively small but continuous supply at widely scattered points. The appropriate water supply technology to service this type of demand could be very different from the technology used to supply high density and high volume use as in a city or suburban situation.

Rural people are increasingly concerned with obtaining not only sufficient water for essential purposes but also water for gardens, lawns and swimming pools to give them a quality of life comparable to city people. If expectations change in this way, and livestock numbers remain at present levels, then rural water supply expansion will be increasingly for quality of life purposes.

1.4 Expected Medium-Term Trends And Changes In Demand

In the agricultural areas current trends in cereal cropping technology and advances in minimum tillage techniques are likely to cause a swing towards more cereal cropping in the traditional wheat and sheep areas in the next 20 years.

Advances in sheep, cattle and pig raising technology are also likely to cause a swing towards more intensive livestock enterprises in the traditional livestock areas in the south—west of the State.

The combined effect of these two trends makes it unlikely that any significant change in livestock numbers in the agricultural areas will occur in the next 20 years. It is therefore predicted that numbers of stock will remain fairly static. In making this prediction it is assumed that the relative profitability of livestock and cereal cropping will remain constant. Changes in relative profitability which result mainly from changes in produce prices are likely to have greater effect than the technology advances referred to above.

Some areas of virgin crown land are to be released for agriculture over the next few years. This land is likely to be used for intensive cereal cropping in the short term, and in the medium term it is expected to cause the State’s sheep population to increase by less than one million. It is not expected that the new land development will have any significant effect on the total numbers of pigs or cattle.

Despite present trends towards reducing livestock numbers in some parts of the pastoral areas, there will always be a Pastoral Industry, for which water supply will be necessary.

In the Kimberley region it is likely that cattle numbers will gradually increase from the present 0.75 million, to 1.0 million. This will occur due to improved rangelands, improved access and improved management. Because groundwater in the Kimberley region is generally deep and expensive to develop, it seems likely that improved surface water supplies will be required to cater for the forecast increase in cattle numbers.

In the areas south of the Kimberley, groundwater has been the commonly used water resource and has normally been adequate, although there are currently two areas of concern:-

(i) The coastal belt from Exmouth to Shark Bay where the existing water supplies are artesian bores of extreme age, and many of these are now in need of replacement. The estimated cost of replacing artesian bores is high ($50,000 each); the shallower groundwater is highly saline; and surface supplies therefore seem to offer the best option.

(ii) The Goldfields and Nullarbor where the groundwater is generally too saline for livestock and surface supplies again seem to offer the best option. Currently extensive pipeline systems supply water for livestock either from darns or from the few good groundwater supplies within each pastoral lease.

A lack of suitable groundwater and the great expense of providing alternative sources has reduced the number of water points in these areas below that which would be considered advisable. This has led to increased livestock concentrations around water points and a consequent overstocking and degradation of the pastoral resource.

2. Rural Towns

2.1 General

All towns within the agricultural areas have been provided with public water supplies (based on local schemes from underground water resources, or from reservoirs supplied from artificial catchments), or based, in whole or in part, on piped supplies from coastal water resources, viz:

The Goldfields and Agricultural Water Supply

The Great Southern Towns Water Supply

The Lower Great Southern Water Supply

The Geraldton Regional Water Supply

The Dathagnoorara Water Supply

The Morawa Water Supply

The Bridgetown Water Supply

Problems of quality and quantity of water exist in some of these supplies.

One notable example exists because the Great Southern Towns Water Supply uses

Wellington Dam as its source. The salinity of water in Wellington Dam has been of concern for several years.

Much more information relating to rural town water supplies will be available in the various reports (and their appendices) which have resulted from the State Study - A Perspective on Water Resources to the Year 2000.

2.2 Policy Re Playing Area Watering Schemes

Playing areas such as ovals for cricket and football, tennis courts, bowling greens, hockey and soccer grounds, and public parks constitute important social amenities in many rural towns, especially inland towns. Because the water supply to some towns is restricted, irrigation of playing areas is not permitted. This policy aims to preserve the water supply for housing and commercial users. In such cases some assistance can be provided to local authorities or sporting groups to establish a separate water supply for irrigating playing areas. Assistance on different aspects of such amenities is available from various Government departments such as Public Works, Agriculture, Youth Sport and Recreation, Geological Survey, Shire Councils, and private consultants. The users of these amenities have observed that the resultant water supply and irrigation facility has, in several instances, fallen short of expectations and that a co-ordinated service would achieve better results.

3. Present Water Resources for Farms

3.1 Introduction

In good rainfall years, farm dams provide water for more than 50 per cent, of the total livestock water demand in the agricultural areas. Up to 30 per cent. of livestock water is supplied from groundwater, and approximately 20 per cent. of livestock water is supplied from Government piped water schemes (Comprehensive Water Scheme). The situation is described in very general terms in Figure 2.

In five shires in the northern wheatbelt more than half the livestock are watered from groundwater only (mostly bores); and in 16 shires in the southern and south—eastern wheatbelt and Esperance sandplain areas, more than half the livestock are watered from dams only.

3.2 Groundwater

Groundwater bores and wells are regarded as the most dependable drought—proof water supply in the wheatbelt but there are often limitations due to water quality, quantity, and distribution. Few groundwater supplies are of domestic quality, and in much of the southern and south—eastern wheatbelt, and the Esperance sandplain, groundwater suitable for livestock is seldom found. In these latter areas, nearly all available groundwater is extremely saline.

A survey of farm water resources on wheatbelt farms in 1970 by the Commonwealth Bureau of Census and Statistics showed that there was at least one usable bore or well on 42 per cent. of all farms. This proportion has probably not changed since 1970.

Much of the agricultural area is underlain by ancient (Archean) rocks which are mostly granite or granitic gneiss. The same area has subdued topography, drainage lines of very low gradient, vast quantities of soluble salts stored in the deeply weathered soil profile, relatively low rainfall and high evaporation. These conditions predispose to very low potential for finding useful groundwater. In fact, the average success rate for locating usable groundwater throughout the agricultural areas is approximately one successful bore from every ten tries. The mean salt content of these usable groundwater supplies is in the order of 4,500 mg L^{-1} total dissolved solids. Very few groundwater supplies in the wheatbelt are of domestic quality.

Good quality groundwater is generally available in a very narrow south coastal strip and in the Perth coastal sedimentary basin. In some parts of the Perth basin between Gingin and Dongara, groundwater is only encountered at depths greater than 150 m. Development of bores at this depth is expensive and this has been a deterrent to adequate water supply development on some farms in the West Midlands.

Although the average success rate for finding usable groundwater in the wheatbelt is approximately 1 in 10, it should be noted that this rate varies between farms and between districts. For example, in the North Kalannie district, where the district success rate was one successful bore from every eight tries, the success rate for individual farms varied from 1 in 2, to 1 in 20. The Lake Grace area has less potential for groundwater development, and the success rate is one usable bore from 108 tries.

The water yield from wheatbelt bores is generally sufficient only for livestock watering. The mean yield per bore is of the order of 10,000 litres per day. Only a very few wheatbelt bores produce sufficient water of quality such that irrigation of a small garden is possible. In general, quantity and quality of water are both limiting, and livestock watering is the only possible use.

Development of groundwater supplies is generally more expensive than surface supplies, due largely to the high cost of exploratory drilling because the average success rate is so low.

3.3 Dams

Of the estimated 76,000 farm dams in the wheatbelt (1970 survey), about 8 per cent either leak or are salt affected. The remaining 70,000 dams are capable of holding water for livestock use and can be regarded as serviceable dams.

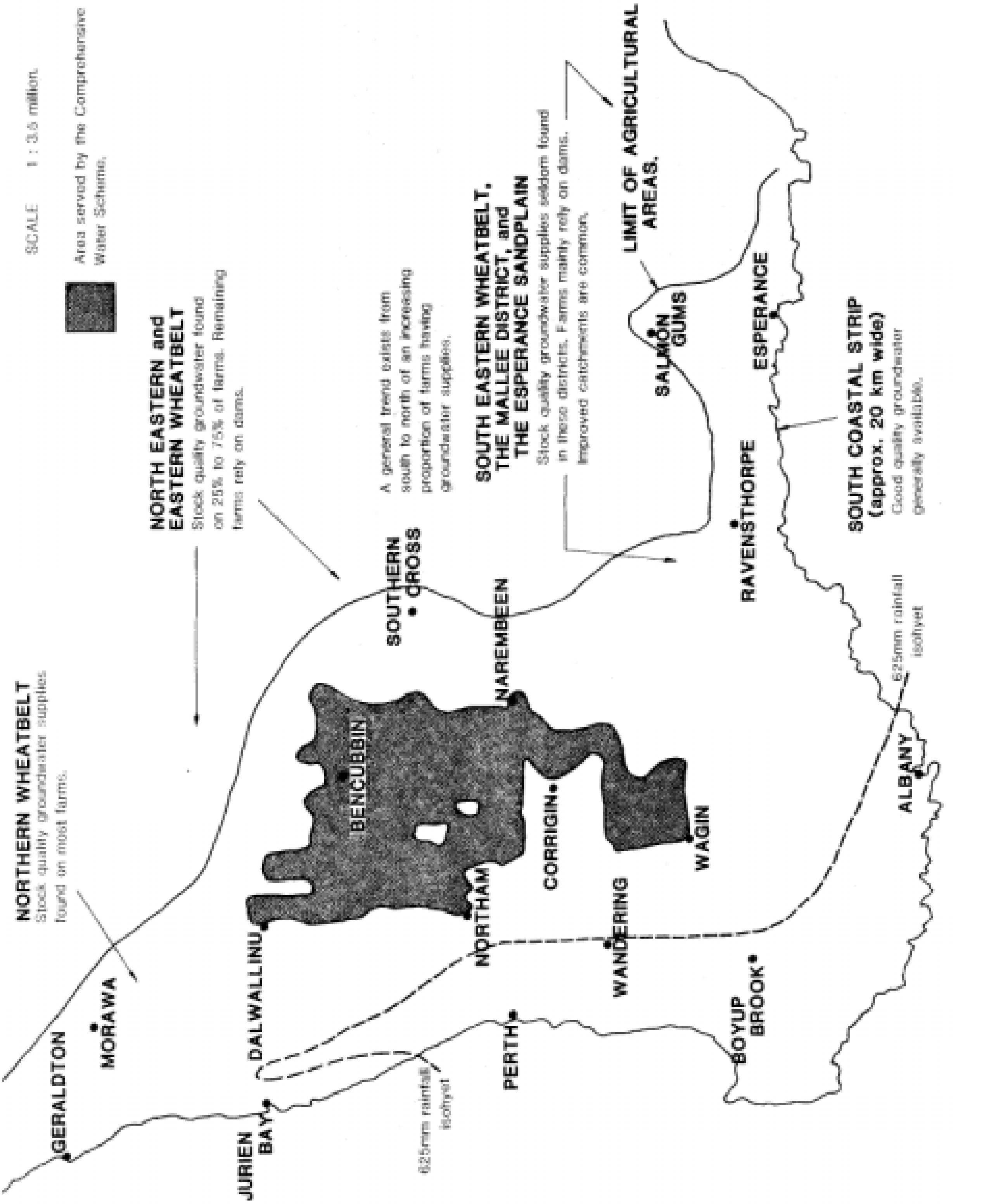
A great many of the serviceable dams are unreliable water supplies due to the combined effects of lack of runoff from catchments, shallow depth of stored water and small size of storage in relation to expected demand from livestock and evaporation loss.

Farm water supply surveys conducted by the Department of Agriculture throughout a large part of the agricultural area have indicated that only about 15 per cent. of all farm dams constitute drought—proof water supplies. The surveys have shown that the greatest cause of dam failure is lack of run—off from the dam catchment. The proportion of dams that are drought—proof is greater in those districts where widespread use of improved catchments is now common.

Because catchment run—off yield varies markedly between years, the proportion of dam failures also varies between years. It has been estimated that approximately 45 per cent. of all farm dams are failures in years of average annual rainfall.

Because it is recognised that catchment quality is of overwhelming importance in wheatbelt water supply technology, the following section is devoted to catchment improvement methods and their potential application in the wheatbelt.

Fig. 2. Map Showing General Water Supply Situation In The Agricultural Areas Of Western Australia.



3.3.1 Catchments

A large proportion of farm dams rely on runoff from natural catchments for filling.

Natural catchments are generally 20 to 400 ha areas of sloping pasture land, and every second or third year this land is normally cultivated and a cereal crop sown. A small proportion of most natural catchments is occupied by high runoff areas such as farm tracks, formed roads, homestead areas and out—cropping rock.

Surface soil textures vary through the full range from sand to clay, but most Western Australian farming soils have a sandy or ironstone gravel surface of variable depth. The amount and frequency of runoff from natural catchments is extremely variable in most districts and therefore catchment improvement techniques, such as contour drains, roaded catchments and flat—batter dams are increasingly being used. The amount and frequency of run—off from improved catchments is much greater than from most natural catchments.

Although catchment improvement techniques are not unique to Western Australia, their use in Western Australia is more common than in other parts of Australia.

The different methods used are as follows:

- diversion banks
- roaded catchments
- flat—batter dams
- bitumen catchments,

and a description of these techniques is given in Appendix A.

3.3.2 Size and depth of dams

A large proportion of dams in the wheatbelt are relatively small and shallow. (The average capacity of wheatbelt dams in 1970 was 1,450 m^3 and the average depth of dams was 3.6 m.) In general, farmers are making dams bigger and deeper now than in the past but this trend cannot extend to all situations as there are frequently site limitations which restrict the depth of new dams. One obvious limitation is the poor holding soil at depth which is commonly found throughout the north—eastern wheatbelt, and another limitation is the presence of salty water tables in many otherwise satisfactory dam sites. Solid rock or semi—weathered rock is also sometimes present and can limit depth and size of dams.

Some farmers have used ring tanks or four-walled dams to successfully store water on sites where dam depth is limited by (i) a shallow salt—water table, (ii) poor holding soil at depth, or (iii) rock. Ring tanks are excavated tanks with above—ground storage which provide a means of storing water in situations which preclude conventional methods. This technique is useful on relatively flat sites, and the dams can be either square or circular in plan.

The above-ground embankment of a ring tank is continuous around the excavation with a pipe laid through the wall at ground level. This allows water to gravitate into the excavation, up to the original ground level. Closing the pipe and pumping over the wall then allows additional storage.

3.3.3 Evaporation from dams

Evaporation loss occurs from all dams in Western Australia at variable rates which increase from approximately 1 m depth per year at the south coast, to approximately 2 m depth per year in the northern wheatbelt. Evaporation losses from dams in the pastoral regions may be even greater. Evaporation accounts for the greatest water loss from storages on farms.

Reduction of evaporation from farm dams by covering with conventional roofing is very costly and not economically justifiable. In some particular seasons, when water carting over long distances is the alternative, a cheap covering material to shade and shelter a dam could be of value. As yet no suitable covering material is available.

3.4 Roof Runoff

Roof runoff provides the high quality water for kitchen, laundry and bathroom use on most farms and pastoral leases.

Provision of art adequate quantity of water for kitchen, bathroom and laundry use is frequently not possible using existing roof areas because available roof areas are inadequate, and alternative sources such as dam or bore water are used to supplement the supply. Rather than use dam or bore water, many farmers prefer to cart water by truck from an off—farm source such as the Comprehensive Water Scheme or an isolated Government tank.

For any given roof area the size of tank storage required increases as the expected maximum period between significant rainfall events increases. A basic minimum roof area exists which will just provide sufficient roof runoff to satisfy a given demand in years of average annual rainfall. If twice the basic minimum roof area is available, storage for two demand months will suffice on the south coast, storage for four demand months is required in the northern wheatbelt, and for 12 demand months in the northern Gascoyne and Pilbara.

In the agricultural areas and the pastoral areas the limiting factor in the provision of adequate roof runoff water for homestead use is the area of roof available. The average area of roof available for harnessing is sufficient for about half the average household demand (excluding garden requirements) in the north—eastern wheatbelt, where average annual rainfall is 275 mm.

3.5 Agricultural Areas Piped Water Supply (Comprehensive Water Supply)

The Goldfields Water Supply which supplies water from Mundaring Reservoir to the Eastern Goldfields, was completed in 1903. In 1907 a branch pipeline was constructed from the Goldfields Water Supply main conduit to supply farmlands north of Tammin.

The area of farmlands served was extended in 1947 and again in 1963—1973 to a total of 3.16 million hectares. The total cost of the work was $50.85 million when it was completed in 1973. This cost includes the cost of supply to the associated rural towns. A map showing farmland and towns supplied is given in Figure 3. The work was in two sections, viz:-

The northern section based on supply from Mundaring Reservoir (the Goldfields and Agricultural Water Supply).

The southern section based on supply from Wellington Dam (the Great Southern Towns Water Supply).

The work was financed from a Commonwealth Government grant and low interest loans, and from State loan funds. The farmers were not required to contribute to the capital costs of the work. Water is sold for domestic (culinary and garden use) and stock watering purposes at by—law prices (as at July 1982) of:— First 1,600 kilolitres per annum — 34% per kilolitre

Over 1,600 kilolitres per annum — 58% per kilolitre

3.6 Other Off-Farm Water Resources

The off—farm sources from which farmers cart water are many and varied, but mainly consist of stand pipes at the extremities of the Comprehensive Water Scheme, or isolated tank storages supplied from rock or roaded catchments or occasionally from a groundwater source. These sources are maintained by the Public Works Department, and it is Government policy to provide a network of off—farm water sources in times of need, such that no farmer will have to cart water more than 40 km. In times of general water deficiency the Farm Water Supply Committee ensures that sufficient water is available at appropriate points from which farmers can cart. This has at times required line hauling of large quantities of water by road tanker from distant sources to water deficient districts.

In times of general water deficiency on farms, water carting by farmers for both livestock and domestic water supply is common. Carting for domestic purposes is a regular annual practice by some farmers.

During the 1969—70 drought, water was carted from outside sources to 2,729 wheatbelt farms or 21 per cent. of the farms. A further 12 per cent. of farms at this time had no stock and this indicates, at least partly, a modification of demand to cope with water shortage. It should be noted that the 1969—70 summer was the most critical period of water deficiency throughout much of the agricultural area for more than 30 years, although widespread water carting has been common in several seasons since then.

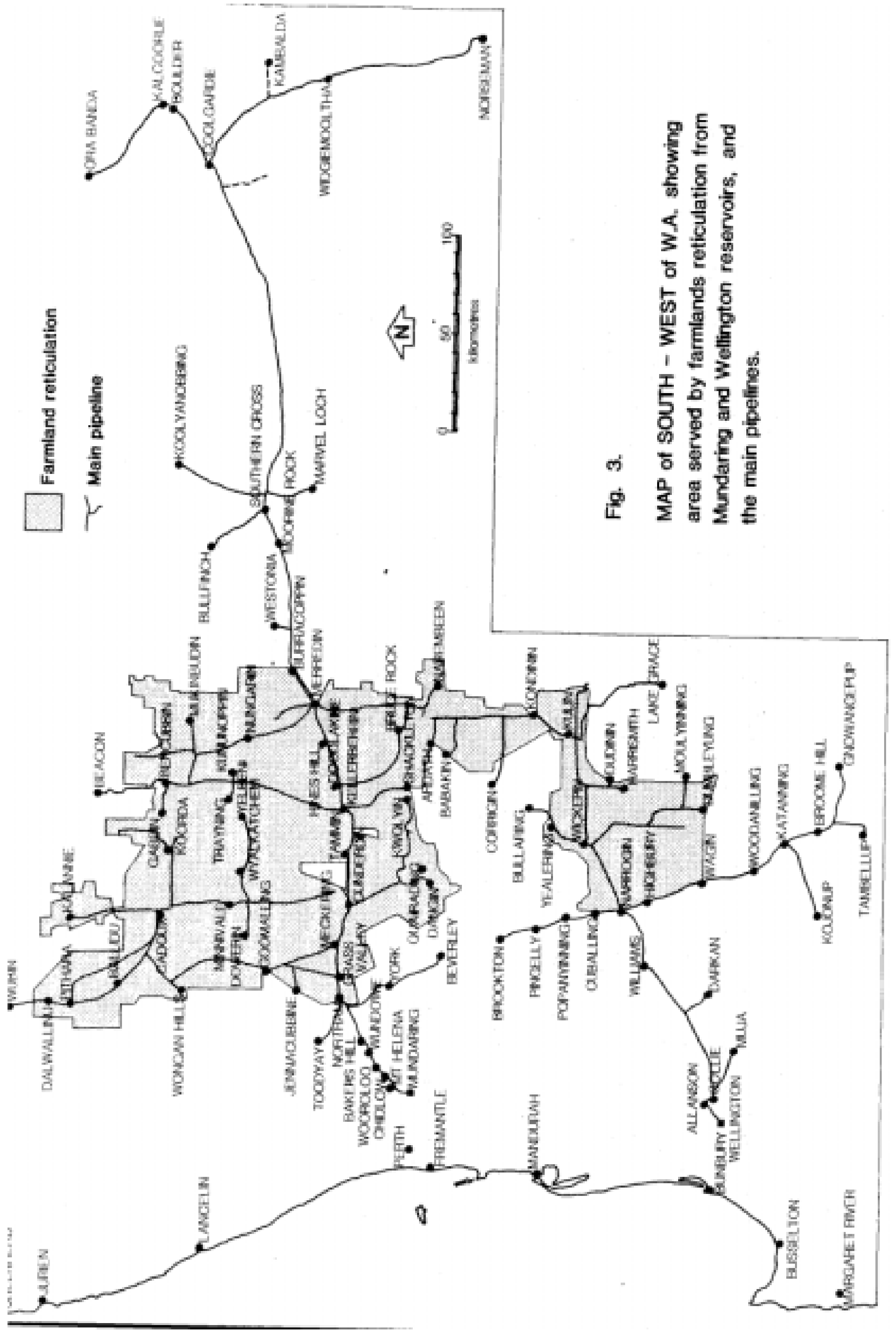


Fig. 3.

MAP of SOUTH – WEST of W.A. showing area served by farmlands reticulation from Mundaring and Wellington reservoirs, and the main pipelines.

In general, it is now thought that the costs of off—farm water supplies in the form of isolated tank storages are far greater than the benefits, (although isolated tanks probably have a better benefit—cost ratio than pipeline scheme supplies), and that the same money if made available through a farm water supply loan scheme, would eventually help many more farmers to develop better water supplies on their own farms. It has been found that the majority of off—farm supplies were only capable of helping a very few farmers for limited periods of water deficiency, and that the widespread water deficiencies experienced in several seasons since 1969, have shown that only a very few isolated tank storages were able to supply appropriate quantities of water.

Despite this general philosophy that isolated tank storage or other isolated off—farm supplies are costly and of little benefit, there are some notable exceptions. Two such supplies are at Mount Roe which is 100 km south—east of Merredin in the eastern wheatbelt, and Dingo Rock which is 40 km north—west of Lake Grace in the southern wheatbelt. Mount Roe dam has a capacity of 85,000 m^3 and Dingo Rock dam has a capacity of 45,000 m^3, and each of these supplies have been drawn on heavily in several seasons since 1969 but neither have gone dry in that time. Many other isolated supplies exist, but these are mostly of limited value because the volume of available water is too small in regard to the likely demand.

4. Future Developments

4.1 Extension of Farmland Reticulation

4.1.1 General aspects

There have been many requests for extension of the Comprehensive Water Scheme to areas of farmlands in the lower rainfall areas. In 1973 the Department of Agriculture identified areas in which the provision of on—farm water supplies for domestic and stock watering purposes was more difficult (and hence more costly) than other parts of the agricultural areas. Since that time several proposals to provide a reticulated water supply to farms in selected areas have been designed and costed. In each case officers of the Department of Agriculture have conducted on—farm surveys to determine, inter alia:

- the deficiency of stock and domestic water supplies in the area; and
- the potential for further development of on—farm water supplies in the area.

In all cases it was shown that the potential existed to supply all stock and domestic water demands from on—farm resources at less cost than the provision of a public supply.

It has not been possible to show that the provision of piped water supplies to farms has increased the stock carrying capacity of the farms. In recent drought periods the stock numbers in shires in which large areas have a reticulated public water supply, have fluctuated as markedly as those which do not have a reticulated supply.

In the past, the provision of the existing reticulated water supply to 3.16 million hectares of farmlands, has been justified, in part, by the need to construct trunk mains to supply water to the associated rural towns in the area, and in part, by the availability of finance by way of a grant and low interest loans by the Commonwealth Government.

With the advent of heavy earth moving equipment and an improvement in on—farm water supply technology, there has been a reduction, in real terms, in the cost of on—farm water supplies. Coincidentally, in later years there has been a reduction in real terms of the financial returns from agricultural production, and an increase in the cost of loan financing, all of which mitigate against justification of increasing the area of farmlands reticulation.

4.1.2 Specific case of the Agaton proposal

The Western Australian Government in May 1979 submitted to the Commonwealth Government a request for financial assistance under the National Water Resources (Financial Assistance) Act 1978, for the development of a reticulated water supply to farmlands in the north eastern agricultural areas.

The proposal, referred to as the Agaton Project, involves developing groundwater resources at Agaton (located west of Watheroo) and the reticulation of 664,000 hectares of farmlands north of the boundary served by the existing Goldfields and Agricultural Water Supply. This area was selected by the State, after consideration of the difficulties encountered in establishing adequate on—farm water supplies, as having the highest priority for the development of a reticulated water supply.

The cost of the project was estimated to be $45.6 million in December 1978. The escalated cost to June 1982 was $64.2 million.

In October 1980, at the request of the Commonwealth, the State undertook a detailed study of the benefits and costs of the Agaton Project, and of the on—farm water supply alternative. The on—farm alternative assumed that the Government would provide increased funds for research and extension services aimed at overcoming the present deficiency in on—farm water in the currently unreticulated Agaton Project area.

The costs and benefits estimated for the Agaton Project and the on—farm alternative, were compared with a base case situation; which was essentially the anticipated situation if there was no government expenditure either to provide a reticulated public supply from the Agaton Project or to increase research and demonstration expenditure on on—farm water supplies.

That study showed that at a 10 per cent. discount rate, the present value of the costs of the Agaton Project was estimated to exceed the present value of benefits (not including social benefits) by $31.68 million or $83 000 per farm, (in January 1981 dollars); indicating that the Agaton Project was not economically viable. Sensitivity analyses indicated that even the most favourable assumptions for prices, costs and production, could reduce the gap between the present value of project costs and benefits by only $1.85 million, to $29.84 million.

For the on—farm alternative, the present value of project costs exceeded the present value of project benefits by $2.47 million or $6,500 per farm (in January 1981 dollars) with a 10 per cent. discount rate. Sensitivity analyses showed that the most favourable movement in prices and costs could only reduce the gap between the present value of project costs and benefits to $1 million.

Proponents of the provision of public reticulated water supplies to areas of farmlands have emphasised the social benefits arising from an adequate and secure water supply. In assessing the alternative means by which water supply requirements in an area of farmland may be satisfied, it is essential that account be taken of these social factors.

If the Agaton Project is to be justified, the economic and social benefits resulting from the project together must exceed the cost of the project. In other words, the social benefits have to be of sufficient magnitude to justify the gap between the economic costs and the economic benefits identified by the study.

The social benefits are readily identifiable, but they are difficult to evaluate in monetary terms. The traditional cost benefit analysis did not include quantification of social benefits. However, the increase in farmland prices that could be expected if the area were reticulated, was considered to provide a reasonable estimate of the value of both the economic and social benefits as it reflects the value placed on those benefits by farmers themselves. By this means the present value of the project benefits was estimated to be between $21 million and $26 million, compared to the present value of the project capital costs (both public and private) of $41.0 million with a 10 per cent, discount rate (January 1981 dollars). Thus, despite the inclusion of an estimate of social benefits, total benefits still fall short of total costs by $15 million to $20 million.

Similarly, it was not possible to quantify social benefits arising out of the on—farm alternative. Of the $7.5 million cost of the on—farm alternative some $2.0 million would be spent in anticipation of social, rather than economic benefits, which were not included in the evaluation of benefits. The value of social benefits need only be $6,500 per farm for the benefits of the on—farm alternative to equal costs, whereas a comparable figure for the Agaton Project would be $83,000 per farm.

Following the release of the report of the Agaton cost—benefit study the Western Australian Government proposed a modified funding arrangement for the Agaton Project. Government stated its policy that a significant level of farmer contribution would be required before the Agaton Scheme could be initiated. A 25% contribution was set as the minimum. This proposal has yet to receive support from the rural community.

The Agaton Project is seen as a test—case in the issue of piped water schemes versus on—farm supply. It indicates that at present, governments cannot afford to help the majority of farmers by providing piped water supplies when estimated construction costs are in the order of $133,000 (1981 costs) per farm.

The Agaton cost—benefit study indicates that the on—farm alternative is more cost efficient. The on—farm alternative may therefore provide a means by which Government can better afford to help all farmers.

4.2 Off-Farm Supplies - Research and Investigation

It is anticipated that there will always be the need for improved off—farm water supplies in rural areas for towns, watering of playing areas, for specific high water—use industries (such as feed—lots and abattoirs), for mining, and as points from which farmers may cart in times of general water deficiency.

It is also anticipated that the demand for such supplies will continue and there is a need for research of different strategies to satisfy such off—farm demands. Such a strategy may involve the integration of pipeline schemes which bring water in from an outside area, the development of local surface and groundwater resources, and desalination of locally—available poor—quality water.

4.3 On-Farm Supplies — Extension, Attitudes and Incentives

Modern water supply methods are being applied on wheatbelt farms as farmers realise the value of these new methods, and as farmer's limited financial and physical resources allow.

The adoption of practices such as roaded catchments and flat batter dams has been particularly rapid in those districts where farm dams represent the only method of on—farm water conservation. A less rapid but nevertheless significant rate of adoption of improved catchments, has been seen in many other areas where some underground supplies were available, but where catchment improvement obviously offered the cheapest method of water supply development.

Some evidence exists which indicates that anticipation of piped scheme expansion inhibits farmer adoption of improved on—farm water supply techniques. Until a clear statement was made of the Government intention with regard to pipeline extension in the East York—Greenhills area, farmers were loathe to improve on—farm supplies, and there were only two roaded catchments in the district in 1974. A statement of changed Government policy (a Public Works Department spokesman stated that if future extension of the CWS occurred, it would not be in the York—Greenhills area) in 1975 brought about a keen interest in improved catchxnents, and we know of more than 80 roaded catchments on farms in that district now.

It is expected that gradual adoption of modern water conservation practices will occur for many years throughout the area presently eligible for farm water loans. It is anticipated that a strong demand for loan funds would result in those areas not presently eligible for loans under the Farm Water Supply Committee Loan Scheme in the first few years of the loan scheme becoming available. Those areas excluded at present are in the part of the State where the potential for large—scale water conservation projects is greatest.

The future development of on—farm water supplies will depend markedly on the type of financial and technicial assistance available.

4.4 On-Farm Water Supplies - Research and Investigations

4.4.1 Introduction

Farm water supply surveys conducted in the agricultural and pastoral districts since 1965 have identified water supply research priorities. Research since then has solved some problems, but many problems remain unsolved. The major areas requiring investigation are discussed in items 4.4.2 to 4.4.7, but it is emphasised that these are the research areas in which investigation is needed, and that because of limited resources only the most urgent aspects of the problems described are being worked on now.

4.4.2 Selection and testing of dam sites for excavated tanks (farm dams) in the wheatbelt

Conventional dam site testing involves the test drilling of a site with appropriate augering equipment, with the aim of finding an appropriate depth and area of impermeable soil. Sub—soils are commonly clays and sandy clays and where these are present to sufficient depth, they are usually satisfactory for farm dam construction in the agricultural areas.

In the north—eastern wheatbelt, some soil materials which would previously have been rejected as unsuitable for dam construction have been found to be suitable. These soil materials are generally found underlying gravel and sandplain soils, and are apparently highly cemented sub—soils. These soils are very hard, and when sampled with a power auger (they cannot be penetrated with a hand auger), are found to have a sand or loamy sand texture.

Because the north—eastern wheatbelt is a harsh environment for development of on—farm water supplies, it is important that suitable tests be developed to allow such sites to be adequately predicted, and thus minimise mistakes in a high—cost water supply area. The alternatives to constructing new dams in this area are:

(i) use of clay—lined dams in valley floor sites. This technique has its problems, and is normally about twice the cost of conventional or unlined dams; or

(ii) desalination. This technique also has its problems. It is expensive, and requires regular daily inspection which makes it expensive on time.

(Both these alternatives are discussed later.)

4.4.3 Sealing of leaking dams

In some parts of the agricultural areas the proportion of leaking dams to good dams is sufficient to significantly affect the rate of farm development. In a survey in the West Midlands in 1968, it was shown that 57 per cent, of dams leaked, and in the north—eastern wheatbelt, approximately 25 per cent, of dams leak.

Some individual properties in these two districts, and in other districts, are more seriously affected.

Some research has been done on the nature of the problem and methods of overcoming it, but the unique problems of the north—eastern wheatbelt are regarded now as a top priority, and a research programme to develop methods suitable for this particular area is now under way. The unique soil profiles and soil materials, combined with a climate of low rainfall and high evaporation constitute the special problems of the area.

It is now clear that more knowledge of the soils is required to be certain that clay lining of excavations can be universally applied throughout the district using locally available clays. It is also necessary to know if suitable membrane materials are available. One material, Rivaseal (its modern equivalent, is Sealcom) has been tested for a 14 year period at Forrestania (approximately 450 km east of Perth), and was found to be satisfactory. Many new materials are now available and we should test the best of those available.

The chemical dispersant, sodium tripolyphosphate (STPP) has also been tested for some time in Western Australia, but has not yet been fully evaluated on north—eastern wheatbelt soils. STPP has a powerful effect in some soils, and although it has been shown to increase dispersion of many wheatbelt sub—soils, it also reduces their structural strength, which can lead to erosion of the treated soils and has sometimes resulted in “blow—outs” or piping failures.

4.4.4 Desalination

In recent years reverse osmosis desalination units of appropriate size for farm use have become available commercially. If fairly readily accessible saline groundwater is available, desalination may be attractive.

Because so little is known about the local operation of small—scale desalination units, and about the likely performance of these particular units, it seems obvious that field testing of the technique should be done.

Two such reverse osmosis desalination units are now being tested and demonstrated by the Department of Agriculture.

4.4.5 Groundwater salinity trends

There is evidence available from farmers, from our own investigations on several particular sites, and from an examination of records kept by the Geological Survey of Western Australia, that there has been a rise in groundwater salinity in the wheatbelt since the 1960’s.

If this trend is universal throughout the northern wheatbelt, where farmers rely almost entirely on groundwater for their livestock water supplies, the consequences are potentially very serious. It is important for us to know if a trend has occurred and what dimensions it has, and to attempt to predict any future trend.

A detailed study has recently commenced of a northern wheatbelt catchment, using several clusters of monitoring bores to identify effects due to soil type, vegetation, land form, topography, etc.

4.4.6 Demonstration of modern surface water supply technology

In many areas, and particularly the northern wheatbelt where groundwater has been the common source of water for livestock, the need to demonstrate modern surface water supply development is now an urgent priority. Because of past reliance on groundwater, many farmers are not experienced in alternative technology, and are not aware of the options available.

Such methods include:

- catchment improvement in the form of roaded catchments and scraped catchments;
- flat—batter or spread bank dams;
- ring—tanks or four—way push dams with pipe inlets and temporary stilling pools for silt removal, and above—ground storage potential; and
- desalination.

4.4.7 Catchment improvement technology

The long—term performance of a roaded catchment is being monitored at Newdegate, in the south—eastern wheatbelt. Because of soil type differences and rainfall character differences, it is important that the performance of roaded catchments be monitored in other districts. This applies particularly in the north—eastern wheatbelt where annual rainfall is the lowest in the traditional farming areas, and rainfall variability is the greatest. A dual purpose farm darn and roaded catchment monitoring station is to be constructed in the north—eastern wheatbelt in 1984.

The long—term monitoring of the performance of a flat—batter dam commenced in 1983 at Badgingarra Research Station.

The monitoring of water quality in farm dams for herbicide content has commenced, following the discovery that a standard herbicide recommendation for control of some weeds on roaded catchments resulted in unacceptable levels of herbicide in the dam water.

4.5 Exploratory Drilling Scheme For Groundwater

During the 1969—70 drought in Western Australia the Government instituted a subsidised exploratory drilling programme. A total of 2,879 bores (overall length 60,000 metres) were drilled of which only 278 were classified successful (yield more than 4.5 m^3d^{-1} and salinity less than 11,000 mg L^{-1} total dissolved solids).

At the time of a follow—up survey in 1976, 125 of the 278 reportedly successful sites had been developed, 7 unsuccesfully. The remaining 153 had not been developed and 24 of these were considered failures by the farmers. Most farmers do not consider it economical to equip a bore unless the salinity of the groundwater is less than 8,000 mg L^{-1} TDS and the yield greater than $7m^3d^{-1}$. This is a higher requirement than was imposed on the 1969—70 drought relief drilling and accounts for the larger number of sites not developed.
The results of that drilling programme are given in the following table.

Table 1. Follow—up survey 1976 — Summary of Results

Area	Total No. bores drilled	Considered successful 1969—1970			Farmers considered failure 1976
		Successfully developed 1976	Unsuccess fully developed 1976	Not developed 1976	
Mount Marshall—Koorda	166	4	2	4	
Westonia	286	7		18	12
Burracopin South	175	8	1	3	
South Yilgarn	106	1			
Mount Walker	145	1		11	4
Kulin—Kondinjn	162	3		7	1
Holt Rock	106	27	1	13	
Nyabing—Pingrup	658	6		28	2
Lake Grace	246	3	1	7	
Ravensthorpe	95	11	2	9	3
Ongerup	407	19		24	
Chillinup	58	3		6	
North Stirling	68	10		6	
South Stirling	138	15		16	2
Fitzgerald	63			1	
Totals	2879	118	7	153	24

It should be noted that the districts drilled have a semi—arid climate and are generally geologically unfavourable for finding domestic or stock quality groundwater. Systematic drilling to test the groundwater potential of different geological environments and various topographical settings has shown that there are preferred areas for future groundwater prospecting.

The 1969—70 exploratory drilling programme was hurriedly organised in response to a severe drought situation and as a result, lacked perfection. Overall, however, it indicated that given sufficient effort, reasonable success could be obtained in some districts. In other districts it could not be recommended.

The cost of this programme to the Government was nearly $200,000.

A continuation of this type of subsidised exploratory drilling programme could be one of the strategies adopted by the Government as an integral part of an overall farm water supply policy aimed at maximum development of on—farm water resources.

4.6 Rural Water Supply Policy Development

In the light of (i) current problems and short—comings in existing farm water supplies, (ii) recent events in years of widespread district water deficiencies, and (iii) the Agaton cost—benefit study findings; the following points are relevant in formulating new policy in regard to farm water supply:

- The high capital costs of farmland reticulation schemes.
- There is considerable potential for improving existing on-farm water supplies using present technology.

Further incentives for farmers to improve their on-farm water supplies are currently being considered. These include

- increasing the scope of the Farm Water Supply Loan Scheme, which incorporates recognition of farmer demand for additional water for social reasons;
- a subsidy or grant scheme; and
- an insurance scheme to protect borrowers against construction failures.

5. Farm Water Supply Advisory Committee

5 1 Committee Structure and Functions

Some policy and administrative aspects related to farm water supplies are administered by an inter—departmental committee known as the Farm Water Supply Advisory Committee (FWSC), which was formed in the mid—l960's.

The FWSC consists of representatives of the Departments of Agriculture, Public Works, Mines, the Treasury, the Transport Commission, and the Rural and Industries Bank of Western Australia.

The FWSC administers the Farm Water Supply Loan Scheme which is designed to help as many farmers as possible to achieve a water supply which is reasonably secure against stock water shortage in any year. The Committee is also responsible for advising the Government on farm water supply policy matters, and for organising emergency supplies of water for farmers in times of regional water deficiency.

5.2 Farm Water Supply Loan Scheme

The loan scheme in its original form was not attractive to many farmers, largely because it was very restrictive in the type of water developments to be funded, and it was a loan only available as a last resort. Modifications made to the loan scheme in 1977 have made the scheme more attractive and the objective of drought—proofing of farming properties is being achieved.

A description of the loan scheme is attached as Appendix B.

In the four years from February 1978 to June 1982, 1,293 applications for loans were received, of which 1,203 were approved, involving an outlay of $5,224,623 or an average of $4,343 per loan. The scheme has required an average of $1.25 million per year for the four year period. Since the end of year one the loan funds have been revolving and the loans have begun to repay capital.

Technical advice is available to loan applicants from the Department of Agriculture and the Geological Survey, although the charges for these services are anomalous. At present no charge is made by the Department of Agriculture for advice, survey, design or supervision in regard to water supply projects, although the Geological Survey makes a standard charge of $300 for advisory visits and a report on the prospects for successful groundwater development on farms of more than 20 ha.

The maximum loan available under the present loan scheme is $7,500, although, under special circumstances, a loan of more than $7,500 may be given with specific approval of the Under Treasurer after recommendation by the FWSC. Farms of above—average size, and farms where only deep underground water is available for development, are examples of special circumstances for which a loan greater than $7,500 may apply. To date no loan greater than $19,000 has been approved, and more than 90 per cent. of loans have been less than $6,000.

5.3 Limitations in the Loan Scheme

To allow more farmers to develop water supplies on their properties for a greater range of potential uses, it has been suggested that the loan scheme should be expanded to cater for a wider range of water supply improvements.

It should be noted that the scope of the present scheme was intentionally restricted to enable the limited State funds used to start the loan fund to benefit as many farmers as possible.

Because the water supply technology and the soils of the Western Australian wheatbelt are unique, recruitment of fully trained technicians and field advisers from outside the Western Australian Department of Agriculture is not possible. Thus, any build—up of staff requirement due to increase of work demand must be gradual, and will occur as a result of on—the—job training given by the existing specialist water conservation staff.

The loan scheme was designed originally to cater for drought—proofing of farms in those districts which have a history of stock water deficiency. Farms in the south-west and lower west coastal districts are ineligible (see map in Appendix B). Eventually it would seem desirable for the loan scheme to be available to all farmers in the agricultural areas, and for all types of water supply improvements.

Pastoralists cannot obtain a FWS loan for water supply improvement on pastoral leases under the present loan scheme, because security in the form of a title deed of the land to be improved is not available. If FWS loans were obtainable for pastoral leases the loan scheme would be more equitable, although it should be noted that loans greater than $7,500 per pastoral lease would generally be required if a loan scheme was to have a significant effect.

The present loan scheme is also restricted in that loan money is only available for specific water supply developments which are designed to increase the available water resources for livestock or homestead use. Funds are not available for:

(i) distribution of water within a property by the use of storage tanks, pumps, piping and drinking troughs;

(ii) exploratory drilling for groundwater; and

(iii) irrigation water supplies.

The maximum loan limit is not itself a restriction, but would require modification or removal if loan funds were available for a greater range of water supply developments.

Some users of the loan scheme have presented a strong case for either the payment of a subsidy or grant, or for insurance to compensate farmers who, despite good intentions, spend money to no avail on exploratory groundwater drilling from which no production bore results, or on construction of farm dams which leak.

It is suggested that until such time that (i) all water supply developments which have a reasonable chance of becoming part of a commercially viable agricultural or pastoral venture are eligible for funding under the loan scheme, and (ii) all farms and pastoral leases are eligible, the loan scheme will not encourage as many of the water supply projects which should be developed in the National and State interest.

Appendix A - Refer Section 3.3.1

Rainfall Collection in Australia[11]

Ian A.F. Laing[2]

Abstract. The current design and construction practices of rainfall collection systems for farms and isolated communities in Australia are described. Emphasis is given to artificial catchment technology such as roaded catchments and spread—bank dams, although the use of contour banks, bitumen and rock catchments, and roof runoff collection is also discussed.

Introduction

This paper describes current rainfall collection practice in the agricultural and pastoral regions of Western Australia (W.A.). In other States of Australia similar practices are used but to a lesser extent, mainly because usable groundwater is generally more plentiful and conditions for runoff from natural catchments are more favourable.

Burdass (1975) presented a detailed account of water harvesting for livestock in W.A.

Water Application

On many rural properties water is collected and stored in reservoirs for subsequent use byeither sheep or cattle. Livestock in the agricultural regions require water for drinking during the annual summer drought when only dry feed is available. In the pastoral regions, livestock often graze halophytic shrubs such as Atriplex and Maireana spp. and may therefore require drinking water throughout the year.Where water is required for a house or garden supply on a farm, the area of garden would seldom exceed 0.1 ha.

In a relatively few cases water is collected and stored in reservoirs for a town water supply,

Rainfall Collection Systems

Collection systems of greatest importance in Australia are those in which runoff from one or more of a variety of catchment types is stored in an excavated earth tank. These

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[1] Paper presented at the U.S.—Mexico Resource Workshop — “Rainfall Collection for Agriculture in Arid and Semi—Arid Regions”, (Tucson, Arizona, September 10—12, 1980).

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reservoirs or farm “dams” are of similar design and construction to those used in other parts of the world. On level sites they resemble Canadian “dugouts”, and on sloping sites they resemble the “charcos” of Arizona.

Because sealing of catchment surfaces with materials other than local clay increases the cost per unit volume of rainfall collection (Hollick, I$_{97}$J$_{1}$ and Laing, unpublished data), it is uncommon for farmers to seal catchments with bitumen (asphalt), and most rainfall collection systems in W.A. rely on a compacted earth catchment.

It is important to note that as the users of these systems are mainly commercial farmers, the various techniques must be economically attractive. For this reason, there is little use made of evaporation reduction techniques in Australia, with the exception of a few instances where mining companies are faced with no alternative but to minimise losses of what water is available. It is generally less expensive to improve catchments than to reduce evaporation and extra catchment improvement can be used to compensate for expected evaporation losses

The ratio of dam volume to catchment size for any particular demand can be related to:

- depth of water storage
- catchment runoff percentage
- rainfall
- evaporation
- rate of water use

Frith, Nulsen and Nicol (1975) described a computer model of a farm water supply system based on an excavated tank storage and improved catchment. The model (DAMCAT) has since been used to calculate the combinations of dam volume and area of improved catchment required to provide the least—cost drought—proof water supply for 1,000 sheep in different districts in W.A. (Frith, 1976).

By considering the total water supply and water demand for livestock on individual farms it is possible to assess the adequacy of existing water supplies. On those farms where supplies are inadequate the DAMCAT model enables a least—cost solution to be determined within the limits of available sites and finance, and the farmer’s preference for different types of water supply.

Catchments and Soils

In W.A., natural catchments are covered with perennial native vegetation or with annual agricultural crops or pastures. Runoff is infrequent and of small amount. Most farm dams are served by natural catchments and this results in a large proportion failing to provide a continuous water supply throughout the year — especially in years of poor runoff. Catchment improvement to increase inflow into farm dams is a common practice, Many of the soils commonly used for construction of improved catchments in W.A. exhibit strong textural contrast between the surface and the sub—soil (duplex soils). A basic aim in catchment improvement is to invert these profiles, so that the original sandy surface soil is replaced or buried by a layer of sub—soil clay. In most cases the sub—soil clay content is greater than 25%. The dominant clay mineral present is kaolinite and the soils often have a massive structure. The cation exchange capacity of these soils is often less than 6 milliequivalents per 100 gm soil, and the exchangeable sodium percentage is normally in the range from 5 to 15%.

Soils not suitable for improved catchment formation are those which contain less than 5% clay and therefore cannot be compacted, and self—mulching or friable clay soils which contain a considerable proportion of the expanding—lattice clay minerals such as montmorillonites and illites.

Catchment Improvements

Catchment improvements will be discussed under the following headings:-

- diversion banks on sloping catchments
- roaded catchments
- spread—banks (or flat—batters)
- bitumen catchments

Diversion Banks on Sloping Catchments

Diversion banks are generally used where surface slopes are greater than 4% and mean annual rainfall is greater than 500mm. Diversion banks on a grade of 0.5% are used to convey runoff to a dam, which would otherwise bypass or not reach it. They can be used to divert runoff from adjoining catchments or valleys or overflow water from other dams. Diversion banks are sometimes used to direct runoff from formed roads, farm tracks, bare and hard areas around homesteads and farm buildings, from outcrops of rock or from areas where the surface soil is heavy clay.

Diversion banks can be constructed with a disc plough, a road grader or a bulldozer. Channels with wide and almost flat bottoms are found to be ideal where large volumes of water may flow. In such cases it is important to use channel gradients no more than 0.5%, otherwise channel and bank erosion may occur.

The “contoured catchment”, as described by Young (1965), is used in South Australia. It is a catchment improvement technique especially adapted to land with a medium to heavy soil texture in the surface and where slopes are generally greater than 5%. Contoured catchments consist of a series of diversion banks which convey water from a smoothed and compacted area, to a stable or grassed waterway leading to a reservoir.

Roaded Catchments

General Concept

It was estimated in l97L~ that more than 2,500 roaded catchments (average size 1.5 ha) were in use on farms in Western Australia. It is estimated that more than 3,500 are in use in 1980.

A roaded catchment consists of parallel ridges (‘roads’) of steep, bare, and compacted earth, surveyed at a gradient which allows runoff to occur without causing erosion of the intervening channels. Roaded catchments promote runoff by the reduction of depression and infiltration losses.

The most important factors involved are:

- increased surface slope
- surfacing with suitable clayey soil
- compacting and smoothing the surface by rolling
- removing weed growth
- steady gradients along road channels and collecting drains to a reservoir

Siting and Design

Enhanced runoff can be achieved by proper design, survey and construction. Road channels should be surveyed on gradients which increase from 0.7% at the outlet end, up to 1.8% at the high end, and should not exceed 400 m in length. Road widths, measured from crest to crest of adjacent roads, should be no greater than is necessary to allow surfacing of the roads with sub—soil clay. Sub—soil is free of weed seeds and, in W.A., is generally more suitable material for catchment surfacing and promoting maximum runoff than topsoil. Roads are normally made 6 m to 15 m wide, and with side—slopes in the range 1 in 8 to 1 in 12. Steeper side—slopes create problems in construction, especially in achieving satisfactory compaction, and increased rilling; and flatter slopes often result in significant depression storage and consequent lowered runoff yields. The runoff from several roads discharges into a flat—bottomed collecting channel which leads to a reservoir. The collecting channel is surveyed and constructed after the roads have been constructed. The normal gradient used is 0.4 to 0.5%.

The theoretical design of roaded catchments was discussed in detail by Hollick (1975), and the practical design and construction was described by Anon. (1956), and Frith (1975). Figure 1 shows a cross—section through a roaded catchment and Figures 2 and 3 show aerial and elevation views.

Construction

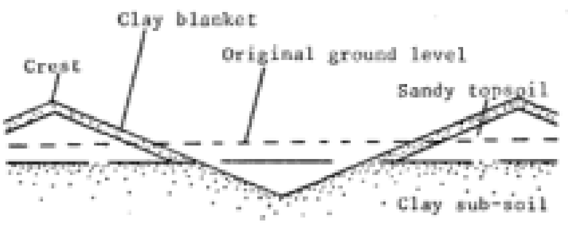
Construction with a road grader generally requires from 10 to 20 hours per hectare with a 90 kilowatt grader, depending on the length, width, and depth of roads, the skill of the grader operator, and the soil conditions. The surface soil is firstly windrowed along the lines of the road crests, operating the grader with its blade flat. Subsequent passes allow sub—soil clay to be taken from the furrow and placed as a blanket on the windrow along the road crest.

Figure 2. An aerial view of a roaded catchment, and two associated 'dams'.

A road grader can leave a catchment surface smooth and with uniform road side—slopes, but final catchment surface preparation should be done with a heavy roller with the soil at or near optimum moisture content for compaction. The best surface for promoting runoff results from compaction with a 6 tonne multi-tyred road roller. Six passes of a roller with the soil at optimum moisture content will give a good surface, and this will usually amount to 4 hours of rolling per hectare.

Weed growth is common after a year or two and is best controlled by application of an appropriate knock—down herbicide. Silt deposits in channels may require mechanical removal.

Figure 1. Cross—section through adjacent roads in a roaded catchment.



Runoff Yield, and Least—Cost System

Continuous runoff measurement from a 3.6 ha roaded catchment at Newdegate (33°S, ll9°E) in Western Australia for a !I year period has shown that in the lowest rainfall year, in which 295 mm of rain was recorded, 71 mm, or 2~4% of the annual rainfall ran off. Annual rainfall equal to, or less than that year (1977) could be expected In 1 year in 5. The mean annual rainfall at Newdegate is 390 mm, and the mean runoff percentage for the 4 year period was 130 mm or 33%. In 1976, 41% of the total rainfall of 418 mm ran off.

For Newdegate the DAMCAT model suggests that the least—cost water supply to provide a continuous supply of water for 1,000 sheep would be a 1,500 m^3 dam and a 1.75 ha roaded catchment. This prediction is based upon 1980 costs of $A 0.60 per m^3 for dams and $A 500 per ha for roaded catchments, and an assumed catchment performance similar to the above example.

Spread—Bank or Flat—Batter Dams

General Concept

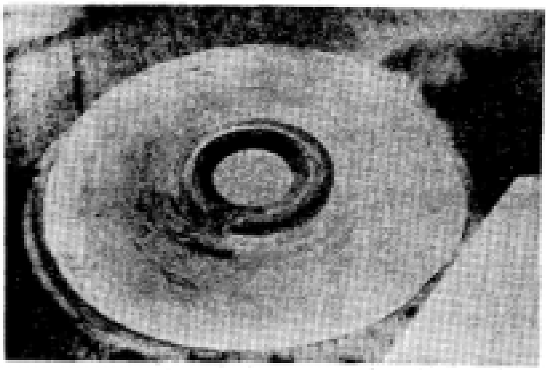
In south coastal districts of Western Australia where soils are mainly sands over clay with the sands often deeper than.0.7m, and rainfall is of low intensity, conventional rainfall collection systems are not successful. In such situations the individual roads in roaded catchments would be very wide (greater than 15 m) to allow a continuous clay cover of' the roads and it has been found that wide roads can create erosion problems and are more costly to construct.

Where the above conditions exist, the topography is generally very flat (surface slopes less than 2%), and good dam building clay is present in the sub—soil within 1.5 m of the soil surface. The particular conditions present in these areas have led to the development of a combined excavated tank and a surrounding area of clay—covered catchment. This water collection system is known as a 'spread—bank 'or flat—batter' dam.

Siting and Design

The excavations for spread—bank dams were originally made with a square plan, but in recent years it has been found that round dams have advantages over square dams due mainly to their ease of construction and maintenance. The sandy overburden is used to form a circular saucer shape and clay is then dug from the centre of the saucer where the water is held. The excavated clay is used to cover the sandy saucer, and form a water—shedding surface with a final surface slope which increases from 1% at the excavation edge to 2% at the outer rim of the catchment. The radial width of catchment is normally in the range from 20 to 50 m, depending on the size of the excavation and the mean annual rainfall. Figure 4 shows an aerial view of a spread—bank dam, and Figure 5 is a diagramatic cross—section.

Figure 3. A roaded catchment, showing where one road discharges into a collecting drain.



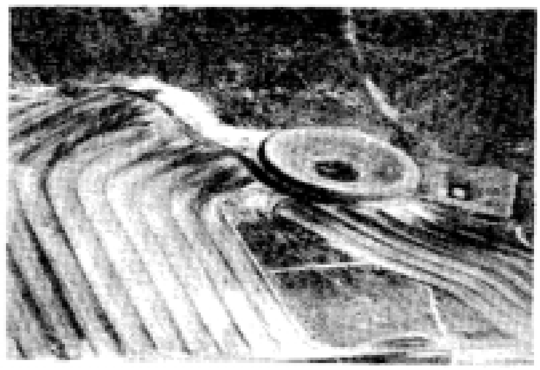


Figure 4. An aerial view of a round spread—bank dam.

Spread—bank dams can be successful where no other design would be suitable. Sites which are flat can be used whereas normally there could be no runoff from such a site. Because the dam provides its own catchment, another advantage is that it may be sited at a high point in the landscape and water can be reticulated at minimum cost.

If there is insufficient clay from the excavation for covering the catchment, some of The overburden may be removed before starting the dam, and sinking the dam deeper into the clay sub—soil. Alternatively, a “borrow” pit may be dug near the dam to provide extra clay.

A fixed ratio of catchment area to dam volume is often used for easy design purposes, Thus, in Western Australian south coastal ‘districts, where average annual rainfall exceeds 400 mm, a ratio of 5 m^2 of catchment per cubic metre of excavation is normally found to be appropriate. It should be noted that this criterion may not result in the most efficient water supply system in terms of dollars outlayed per cubic metre of water supplied.

It is possible on both conventional and spread—bank dams to store water above previous ground level by laying a pipe through the wall and pumping water over the wall after the excavation has filled by gravity flow. In spread—bank dams, the design usually includes an embankment around the circumference of the reservoir, and an inlet pipe is laid through this embankment at the lowest level of the catchment. The embankment not only allows water to be stored at greater depth than would otherwise be possible, but it is also an important and convenient supply of clay which can be used for spreading on the catchment when maintenance is necessary.

Figure 5 – Cross-section through a spread-bank dam and one side of its catchment

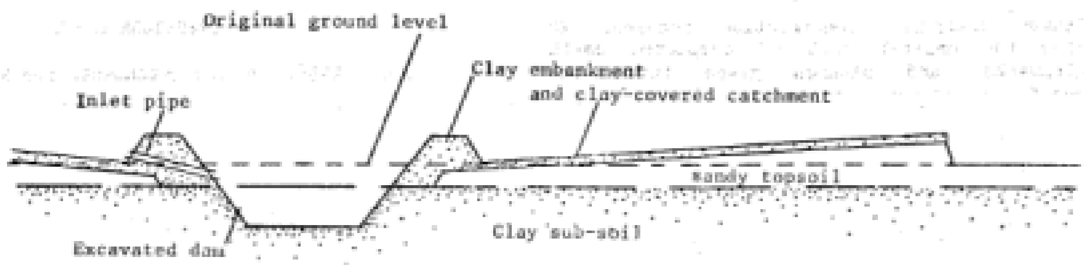


Figure 5 - Cross-section through a spread-bank dam and one side of its catchment.

Construction

Spread—bank dams are best constructed with a bulldozer or scraper, and a grader. A bulldozer is suitable for small systems, up to 1,500 m^3 capacity, but bigger systems are more economically done with a scraper due to the longer earth—moving distance. A grader will always be needed to give a sufficiently smooth finish to the catchment area. In some soils compaction with a multi—tyred roller may be necessary.

The first step in construction is to push the sandy overburden from the site of the excavation, and to place the overburden as a wide circular saucer with a steady gradient of 1% to 2% sloping inwards towards the excavation. On uneven sites it will be found that considerable cut and fill may be required to achieve uniform catchment gradients. Excavation into the sub—soil clay then allows a clay blanket to be applied over the top of the overburden. It is important that the clay of the excavation is continuous with the clay cover of the catchment to avoid loss of water by seepage from the upper part of the excavation. The clay lining the upper part of the excavation should be at least 1 m thick.

A road grader can be used continuously during construction,

- to spread the overburden out at a uniform gradient
- to spread the clay blanket on the catchment area
- to give a standard blanket thickness of 0.1m and
- to ensure the final catchment surface is smooth, compact, and free of major depression storage.

Both Stanton (1977) and Shepherdson[3] (1979) have described design and construction aspects of spread—bank dams, and Pepper (1978) has developed formulae to calculate volumes of earth moved in construction.

Runoff Efficiency

Experience in Western Australia suggests that spread—bank dams yield at least as much runoff as roaded catchments made from the same type of clay. This occurs despite the much flatter water—shedding surfaces, which result in minimal losses when left bare, smooth, and compacted. Because the catchment area on a spread—bank dam surrounds the reservoir, the total length of flow path for runoff from the catchment perimeter to the reservoir is minimised.

Bitumen and Rock Catchments

In recent years the Public Works Department (P.W.D.) in Western Australia has used bitumen catchments rather than compacted earth catchments, to fill reservoirs for small town water supplies. This is largely because the water quality is more acceptable, runoff is more reliable and maintenance is required less regularly. Kelsall[4] (1968) described the recommended construction techniques in detail.

[2]Bitumen catchment construction requires 20 times the capital cost of' compacted earth catchments, and bitumen gives twice the runoff. Maintenance costs of both types are small in relation to initial capital cost. The cost of rainfall collection from bitumen is therefore very expensive, and is the reason why little use is made of the technique by farmers in Australia.

The P.W.D. have also harnessed the runoff from granite rock outcrops in the dry inland areas of Western Australia (Davis, 1977) wherever this was possible. It usually required the construction of contour drains made of masonry or concrete to divert runoff from the rock to a reservoir. The reservoirs were normally either excavated earth tanks in an area adjacent to the rock outcrop, a circular reinforced concrete tank, or a concrete wall across a "valley" in the rock.

The runoff yield of rock catchments varies widely between different catchments, but many give more than 70% runoff on an annual basis.

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Davis (1977) presented a comparison of capital costs of rock, roaded and bitumen catchment to yield 4,500 m^3 of water in a 300 mm annual rainfall area. The costs were, in 1977 Australian dollars, 8,000, 11,000 and 40,000 respectively. The comparison indicates the advantage of rock catchment which requires both low capital input and low maintenance. It should also be noted that the capital cost of roaded catchment in this comparison was only 40% more than rock catchment. These figures are much greater than corresponding figures from farmers' constructions on their own farms, but the comparative levels of costs are realistic.

Roof Runoff Collection for Household Use

It is common on farms in Australia for roof runoff, from galvanised iron, cement or baked—clay tiled roofs, to be collected in galvanised iron guttering and stored in galvanised iron, concrete, or fibreglass storage tanks for household use. Provided roofs and gutters are kept clean, and the storage tank cannot be contaminated, this water is of excellent quality and is normally suitable for kitchen use without treatment. Perrens (1975) discussed the relationship of roof area, storage capacity and water demand for the Armidale district of New South Wales. He concluded that the prime requirement of such a system is an adequate roof area, and for the particular case studied, the storage capacity was of secondary consideration. Some preliminary calculations based on Perren's model indicate that his general conclusions apply throughout a large part of Australia where long dry periods are common between significant rainy periods.

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