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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Contents

1. Introduction

This paper defines districts having the greatest difficulty (and/or cost) of establishing and maintaining on-farm water supplies for livestock and homesteads in the cereal and sheep zone of south-western Australia. It is an update of an earlier paper on the same topic (Laing, 1973).

The objectives of the paper are to alert water supply planners to regional differences in water supply development potential, and to assist rural water supply policy and planning. A more general statement describing rural water supplies in Western Australia is presented in Laing (l983b).

Whilst there are few, if any, farms on which reliable water supplies for homestead and livestock cannot be constructed, there are large differences in the costs of providing those supplies. Thus, the differences in difficulty of providing on—farm water supplies can be viewed as differences in the investment required.

The costs and reliability of supply depend upon the factors listed in Section 2.

2. Factors Affecting Water Supply

Physical or environmental factors of importance in establishing and maintaining reliable on-farm water supplies are listed here and dealt with in detail below;

- rainfall and runoff;
- evaporation;
- soils, landform, geology, groundwater hydrology.

Other factors of importance are the availability of:

- finance
- technical expertise for:
    - design,
    - survey, and
    - supervision.
- construction equipment and contractors
- appropriate materials, such as:
    - concrete,
    - flexible membrane liners,
    - bore casing,
    - piping, etc.

Prout (1969) showed that as livestock numbers increased on farms in the South Stirlings district the investment in water conservation per sheep equivalent decreased. The farms surveyed were in various stages of development. Thus the stage of farm development and overall investment in the property are of significance, as are farmers' attitudes to different water supply options.

The operation, maintenance and management of water production systems also affect the reliability of supply. The important physical factors are discussed in greater detail in following sections.

2.1 Rainfall, runoff and evaporation

The amount and variability of annual rainfall becomes less favourable for water supply design from the south-west to the north-east. In that direction the average annual rainfall decreases (Figure 1), and its variability increases (Figure 2).

For storms of any duration rainfall intensity generally decreases going inland to the wheatbelt from both the west coast and the south coast (Instn. Engin. Aust., 1987; and Figure 3). From Figure 3 mean annual rain per rainy day (MRPRD) can be seen to be greater in the north and north-eastern wheatbelt (5.0 to 6.5 mm) than in the lower Great Southern and south-eastern wheatbelt (4.0 to 4.5 mm).

Lower rainfall leads to proportionately less runoff, and more variable rainfall leads to more variable runoff. These factors require the catchment area of a water supply system to be greater or that catchments be more effective (i.e. have higher runoff coefficients).

The amount of annual evaporation increases from south to north (Figure 4). To allow for greater evaporation losses in the northern districts, dams must be deeper.

2.2 Saline groundwater

As a result of development of land for agriculture most major valley floors in the cereal and sheep districts are now underlain at shallow depth by highly saline groundwater. Construction of farm dams in the valley floors is severely restricted as a result of saline groundwaters which frequently occur within 4 m of the soil surface. Thus, many otherwise satisfactory sites for farm dams are now unusable.

There are many examples of dams constructed in valley floors which have been rendered useless by saline seepage.

2.3 Soils

A great variety of soil materials are found in the cereal and sheep region of Western Australia. Although many are satisfactory for water conservation structures, others are not suitable for one or more reasons.

Problems with water-holding ability of dams; and the stability, construction and water shedding properties of roaded catchments are considered in following sections.

2.3.1 Permeable subsoils

There are two distinct subsoil types within this group:(i) Mottled-zone subsoils of the lateritic profile. These subsoils commonly contain 30 to 35 per cent clay and often appear pink when exposed in embankments. The in situ soil material is mottled with varying amounts of pale yellow, brown to dark reddish brown colours, and frequently includes soft ironstone concretions. The subsoils of the jarrah-belt and the lateritic sandplain in the West Midlands are typical of this soil type.

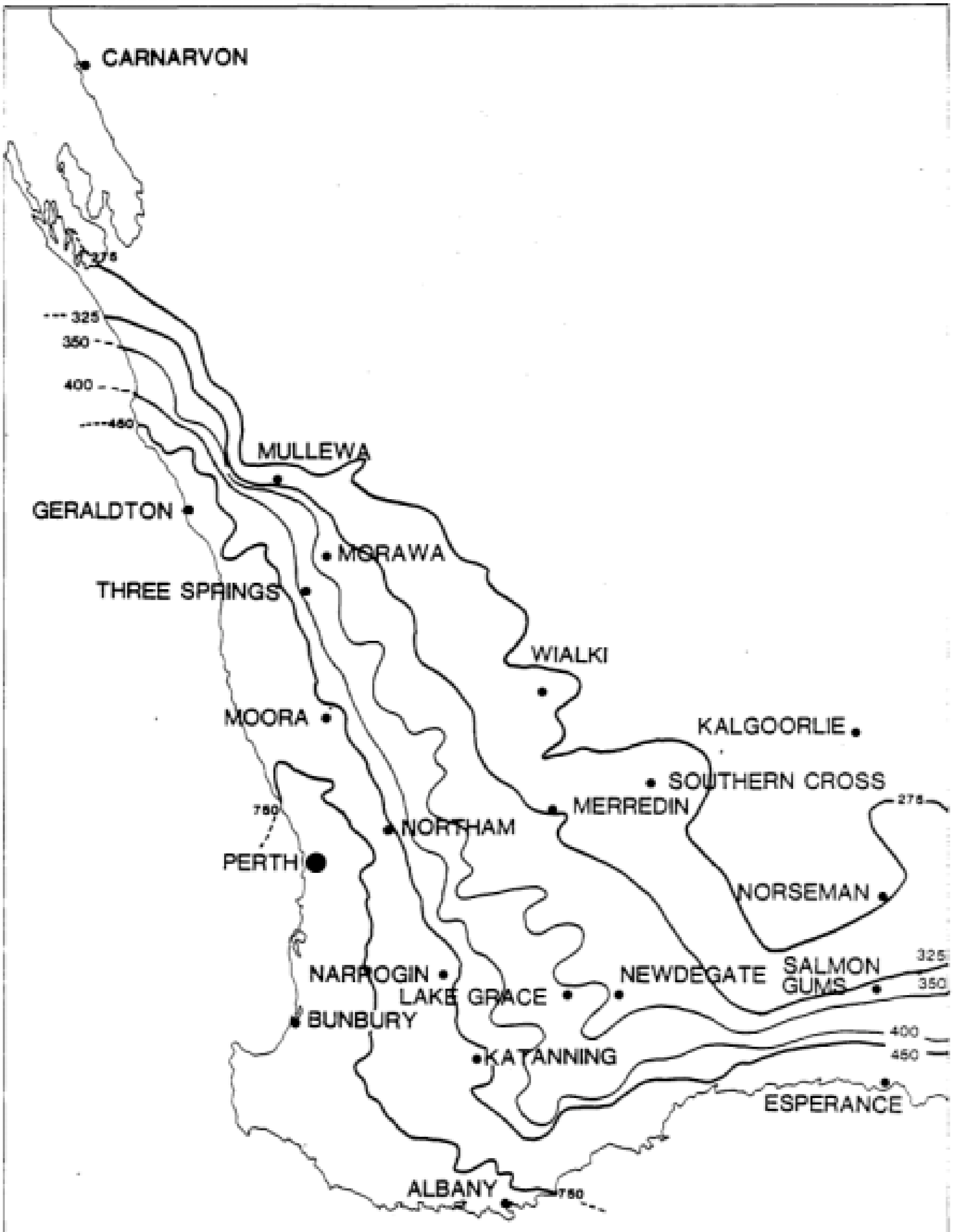

Figure 1: Average annual rainfall (mm) in the agricultural regions of Western Australia

Figure 2: VariabIlity of annual rainfall in the agricultural regions of Western Australia
Source : Natmap(1986)

Figure 3: Mean annual rainfall per rainy day (mm) in the agricultural regions of Western Australia
Source : Laing(1981)

Figure 4: Average annual pan -evaporation (mm) in the agricultural regions of Western Australia

Source : Natmap(1 986)

Mottled zone subsoils would normally occur beneath landforms similar to Belmunging or Balkuling surfaces (Mulcahy and Hingston, 1961), or less frequently beneath Quailing (erosional) or Kauring surfaces.

(ii**)** Pallid-zone subsoils are mostly off-white to very pale grey and are often found underlying red-brown sandy clay barns throughout the north eastern wheatbelt. They commonly contain 25% clay, and may be cemented by silica (McCrea, 1985).

These soils are representative of the Merredin, Booraan, and Collgar soil series described by Bettenay and Hingston (1961).

The clay content of these soils would normally lead to a low hydraulic conductivity, but the unique structural characteristics conferred by in situ weathering, gap-graded particle size distribution and changes induced by tree roots have resulted in the presence of preferred-pathways of very much higher hydraulic conductivity than the general soil matrix.

2.3.2 Structured cracking clay soils which are associated with dispersive subsoils

These are soils with high clay content which often exhibit gilgai or crab-hole micro—relief, e.g. red—brown, self—mulching and gilgai soils of the Berkshire Valley, Bindi Bindi, Pithara-Dalwallinu, and Ravensthorpe districts. Outcropping basic rock, floaters and shallow profiles onto rock, are common. The original vegetation on these soils was salmon gum and gimlet woodland. Earthworks are often unstable and darn embankments and contour banks are prone to piping failure and tunnelling.Mulcahy and Hingston (1961) described similar soils as representatives of the York geomorphological surface which occurred where the parent material was a basic rock. These soils contain significant amounts of smectite.

Runoff from catchments on such soils is much less dependable than from hard-setting soils. Due to the high shrink-swell ratio and the instability which results from alternate drying and wetting cycles, the cracking clay soils are quite unsuitable for roaded catchment construction.

2.3.3 Moderately structured soils with high lime and salt content

Soil groups associated with salt lake country have an accumulation of soluble salts either at the surface or at a shallow depth in the soil profile. These soils can be described as shallow gypsiferous and saline loams and brown calcareous earths. The soils are usually underlain by shallow (< 4 m) saline groundwater and locating dam sites with sufficient depth and suitable water holding material is difficult.

The high salt and gypsum content in the surface soils also reduces the efficiency of roaded catchments due to the catchment surface tending to crack and crumble with time (Pepper and Morrissey, 1985).

Significant areas of these soils are found adjacent to the chains of salt lakes which occur in the southern and central wheatbelt, and in the Salmon Gums district. The problem soils identified here are representative of the (i) calcareous woodland soils, which previously grew Kondinin blackbutt, saltbush, morrel and boree, and (ii) salmon gum woodland soils, which are both described by Teakle et al. (1940) as soils of the valley floor in the Lakes District.

2.3.4 Insufficient depth of soil

The depth of excavation, and therefore the potential depth of water storage, is limited by the presence of shallow rock. This can be a problem on almost any farm, but particularly in those districts where young soils occur and on which soil depths are limited due to the relatively short period of soil formation.

2.3.5 Low clay content in surface soil

Surface soils of low clay content (sand, loamy sand, gravelly sand), and land with very low slope (< 1%) have low potential for generating runoff, and are the main reason for the use of improved catchments such as roaded catchments, scraped catchments and flat batter dams in the Western Australian cereal and sheep districts.

In those situations where the surface soil horizons of sand or gravel are deeper than about 0.5 m (over a subsoil clayey horizon), roaded catchments are not economical or practical and flat-batter dams may be recommended. This limitation results in less flexibility in water supply planning options, and often involves greater expense.

3. Prospects for Groundwater

The likelihood of finding substantial amounts of usable groundwater, or new groundwater supplies, on farms underlain by the Archaean Shield is not great. Much of the exploration for groundwater in this region has yielded, at best, small quantities of poor quality water usable only by livestock.

The overall success rate has been less than one useful supply from 10 exploratory holes (Lord, 1971; Laing, 1977b). Most unsuccessful holes have been either dry or the water too saline. Future success rates are not expected to improve and with the increased costs of equipping bore holes, the cost of developing groundwater supplies will increase. This scenario suggests that there will be less emphasis on groundwater development in the future, and more emphasis on surface water options.

Despite this relatively gloomy outlook for groundwater development it should be noted that improved remote sensing techniques and the likelihood of much wider use of recently developed geophysical exploration techniques provide some optimism for greater precision in bore siting in the future. There is currently considerable interest in the productive use of shallow stock-quality groundwater which has been identified as the causal agent of hillside saline seepage problems. Undoubtedly the installation of bores or drains on some hillside seepages will result in the development of useful and reliable water supplies for livestock. The likely number and reliability of these shallow groundwater supplies are not known at present.

Laing (1983a) reported that salt content of groundwater in 76 usable bores on farms in the northern wheatbelt, increased by an average of 80 mgL^{-1} total dissolved solids (T.D.S.) per annum in an 8 year period 1968/69 to 1976/77. The total net rise in T.D.S. was 630 mg L^{1} or 17 per cent. In this period, annual rainfall in the region was considerably lower than the long-term average possibly causing decreased recharge of aquifers, and further study is required to determine the extent of the problem and whether these changes are irreversible. A current study by the Geological Survey of Western Australia on a catchment at Winchester (near Carnamah) should allow better prediction of groundwater quality trends (McGowan, 1985 and 1988).

4. Geographical Trends in Water Supply

In the case of surface water supplies consisting of farm dams and roaded catchments, an overall increase in costs per livestock unit, or per household served, occurs from the south-west to north-east. This trend is closely related to increasing evaporation, decreasing rainfall, and increasing variability of rainfall from south-west to north-east. As a result there is a need for larger, deeper storages and larger catchments for a given level of demand in the north-east.

The water supply simulation model DAMCAT (Davies and Denby, 1988) can be used to compare the relative size and costs of water supplied at different locations, and two actual examples of water supply systems to cater for 1000 sheep are given in Table 1.

Table 1.A comparison of roaded catchment area, farm dam volume, and capital costs to cater for 1000 dry sheep equivalents (DSE)* at two wheatbelt locations

Location	Dam volume	Roaded catchment area ha	Capital costs	
			Total $	Per DSE $
Katanning	2000	1.5	4000	4
Merredin	4000	3.3	7000	7

A general trend also exists from south to north of an increasing proportion of farms having groundwater supplies, and an increasing proportion of livestock watered on groundwater supplies. This trend is shown in Figure 5.

The higher mean rain for rainy day in the northern and north-eastern wheatbelt compared to the southern districts (see Figure 3) results in more favourable opportunities for groundwater recharge. The greater availability of groundwater in the north also reflects more favourable soil and geological conditions for groundwater occurrence and recharge. The subsoils of the northern wheatbelt are generally higher in sand content, have a less massive structure, and a higher hydraulic conductivity, than the more clayey subsoils of the southern wheatbelt. Evidence to support this trend is the geographical distribution of leaking dams. Laing and Pepper (1976) showed that the failure rate of dams due to leakage was very low in the southern wheatbelt (2 to 3 per cent), intermediate in the central wheatbelt (S to 7 per cent), and higher in the north-east wheatbelt (, 10 per cent). These data suggest a regional increase in subsoil hydraulic conductivity from the south to the north and north-east.

Footnote: -

*A DSE is defined as a non-lactating sheep, of liveweight 45 kg, in forward store condition and grazing a maintenance diet of subterranean clover or similar. For water demand assesment the following conversions normally apply

1 sheep of any description = 1 DSE
1 pig of any description = 2 DSE
1 beast (cattle) of any description = 10 DSE

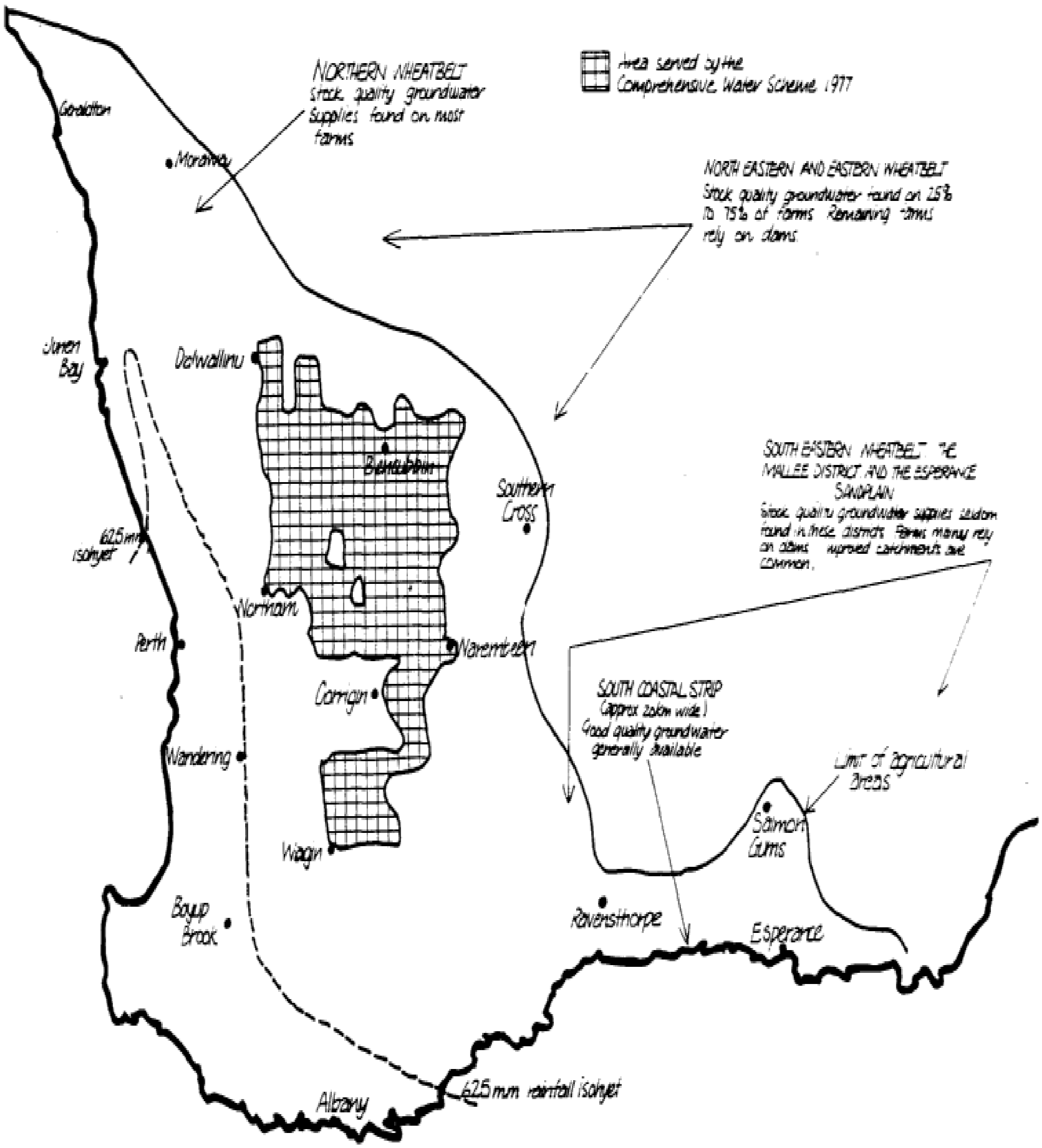

FIgure 5: Geographical trends in groundwater availability on farms

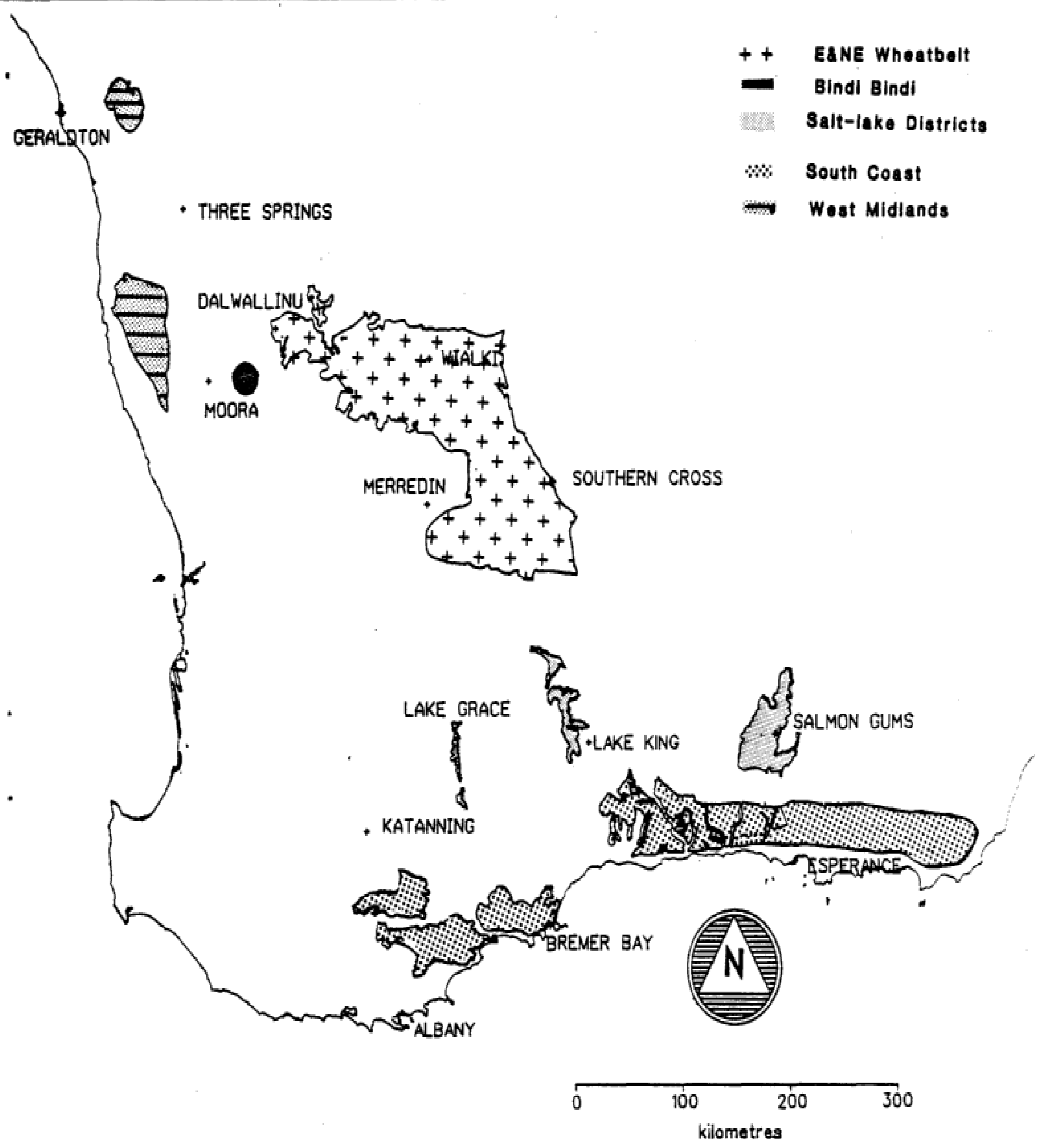

Figure 6: Areas of greatest difficulty for development of reliable on-farm water supplies.

5. Districts having Specific Water Supply Problems

Each district nominated below is defined on the map in Figure 6 in terms of the dominant soil association in the district. It should be noted that similar soil associations occur in districts other than those mapped, and the map should only be interpreted as giving an indication of the likelihood of problem occurrence.

5.1 Eastern and North-eastern Wheatbelt

These districts extend from Perenjori, through Kalannie and Mukinbudin, to Hyden. They include the districts which adjoin those parts of the central wheatbelt already served by the Comprehensive Water Scheme, and adjacent districts of hydrological similarity.

Approximately 25 per cent of farms have no usable groundwater and those farms are therefore entirely reliant on dams and catchments. Another 25 per cent of farms have sufficient groundwater for all their livestock water needs, and the remaining 50 per cent of farms use both groundwater and surface water to supply their livestock water needs (Frith, 1977, and Laing, l977a and l977b).

There are specific problems associated with;

- selecting sites for excavated dams
- selecting sites for roaded catchments, and
- high evaporation and low rainfall.

5.2 Bindi Bindi

At Bindi Bindi, about 30 farms have difficult soil conditions that are associated with shallow soils formed on basic and ultrabasic igneous rocks.

Useful groundwater is generally found in very small quantities in this environment, and approximately 50 per cent of farms have insufficient groundwater for their needs.

The specific problems for surface water supplies are lack of soil depth, strong soil structure and dispersion which affects embankment stability, and the amount and frequency of runoff. Shallow, saline watertables are common in depressions. Problems of high evaporation and medium to low rainfall are also present.

5.3 Salt-lake Districts

These districts occur adjacent to the salt-lake channels throughout the southern and central wheatbelt and at Salmon Gums.

Usable groundwater is very rarely found in this environment.

The specific problems encountered are mainly related to the unique soil conditions for construction of improved catchments, instability of soils used for catchments and dams, and poor potential for deep dams due to the common occurrence of salt watertables and to poor water-holding soils in some situations. With these soils only the upper horizons (< 30 cm) can be used for roaded catchment construction because at depths greater than 30 cm the presence of lime, gypsum and salt produce an unstable soil surface.

Successful improved catchments on such soils must be constructed with only shallow relief to avoid excavating into the unstable, crumbly clay. The occurrence of these soils, and related water conservation problems have been described by Pepper (1987).

The general problems of moderate to high evaporation, and low rainfall are also present.

5.4 Northern Wheatbelt

This region is defined as being east of the Darling Fault (or the Midland Railway line from Coorow to Mingenew) and north of Marchagee and Wubin. Because the precise boundaries of the region are not known and our knowledge of the district water supply problems is sparse, the region has not been shown in Figure 6.

Although usable groundwater is available on 90 per cent of farms in the region, and more than 60 per cent of livestock are watered on groundwater, the average salinity of this resource is known to be rising (Laing, l983a). Despite the general availability of groundwater, in some major valley floors there are farms on which no usable groundwater is available. On those farms which only occupy the valley floor the prospects for either groundwater or surface water development is poor.

The use of surface water in this region has not been fully developed due to the widespread use and availability of groundwater. There are some difficult soil conditions for dam siting near Three Springs, on the geological formations associated with the talc mine and the surrounding country. These soils are shallow, and in places overlie cavernous chert. In the valley floors where usable groundwater is no longer available there are saline groundwaters at shallow depth. Problems of high evaporation and medium to low rainfall are also present.

5.5 South Coast

A large expanse of sand and gravel plain along the south coast has been developed for agriculture since the 1950s. This land extends from Frankland and Rocky Gully in the lower Great Southern, through the North and South Stirlings, Wellstead, Kojoneerup, Gairdner River, Jerdacuttup, Esperance, Boyatup and Neridup.

Clearing of these soils for agriculture has upset the hydrological balance. Saline groundwaters are rising in many valleys, causing saline seepage into existing dams. In the horticultural areas of the Lower Great Southern, such as the Frankland district, this is posing a threat to the expansion of viticulture and other horticulture and also to the viability of existing orchards.

Usable groundwater is generally restricted to a near-coastal strip of land approximately 20 km wide. Further inland groundwater is normally too saline, even for livestock use.

Along the South Coast where the topography is suitable, flat-batter dams provide a viable option to conventional excavated dams (Laing et al., 1980) for homestead and livestock water supplies.

5.6 West Midlands and Eradu

This region lies to the west of the Darling Fault and north of Gingin. Almost the entire

region has access to groundwater of good quality and quantity but throughout a large part of the region the depth to usable water is more than 100 m. The cost of each bore is therefore substantial. Irrespective of whether a farmer wants to cater for 300 or 3000 sheep, the supply of water to those sheep from a groundwater source will cost the same and the average total cost (1988 dollars) is about $40,000 per bore. Thus,even though groundwater is readily available throughout the region, the establishment and maintenance of a supply is expensive, largely due to the depth of the water.

Some properties throughout the region have surface water options, but there are many situations where subsoils are very permeable and almost the entire region has surface soils of very low clay content which results in little runoff.

6. Frequency Of Regional Water Deficiency Declaration

The frequency and severity of regional water deficiency in Western Australia is inversely related to the availability of usable groundwater on farms (see Figure 5, and Anon, 1974).

Because very few groundwater supplies have been developed on farms in the southern and south-eastern wheatbelt those districts have experienced more frequent and severe water supply deficiencies than other farming districts in the years of low rainfall since 1969.

Statistics regarding the frequency of water deficiency declarations of shires in the period 1977/78 to 1986/87 are presented in Table 2, with the shires ranked in decreasing frequency of declaration in the 10 year period. The shires are also divided into two major geographical groups comprised of shires in the Great Southern, southern wheatbelt and south-eastern wheatbelt, and shires in the northern, north-eastern and eastern wheatbelt. These two geographical groupings broadly separate those districts which have little or no usable or developed groundwater, from those districts which have significant groundwater supplies on farms.

In Tables 3, 4 and 5 the same data is presented with the frequencies of water deficiency declaration weighted in different ways, and in each table the shires have been ranked using that weighted index.

In Table 3 the frequencies were modified depending on the proportion of the shire area declared in any year and the weighted frequencies can be thought of as shire-years. This analysis accounts for annual frequency of water deficiency and proportion of the shire affected, but does not account for seasonal severity of water deficiency in terms of duration or amount of water carted. No account was made of the size difference between shires or the different livestock numbers between shires.

From Table 3 it can be seen that during the 10 year period, 1977/78 to 1986/87, in 10 shires in the Great Southern and south-eastern wheatbelt the weighted frequencies of water deficiency declaration ranged from 3 to 5 shire-years; and in several other shires in the same region the weighted frequency was lower. In the north-eastern wheatbelt during the same period, one shire had a weighted frequency of water deficiency declaration of 5 shire-years and in another three shires the weighted frequency was in the range of 2 to 3 shire-years. Shires in the eastern, central and northern wheatbelt districts were declared water deficient less frequently than in other districts.

Table 2. Frequencies of water deficiency declaration of shires and parts of shires in Western Australia, as the number of years in the 10 year period 1977/78 to 1986/87

Shires in the Great Southern, southern wheatbelt, and south—eastern wheatbelt		Shires in the northern,north-eastern, and eastern wheatbelt	
		Mt Marshall	6
Dumbleyung	6		
Broomehill	5		
Kent	5		
Kuhn	5		
Lake Grace	5		
Woodanilling	5		
Katanning	4		
		Kondinin	4
		Mukinbudin	4
Wagin	4		
Wickepin	4		
Cuballing	3		
		Koorda	3
Pingelly	3		
		Westonia	3
Beverley	2		
Brookton	2		
Corrigin	2		
Gnowangerup	2		
Kojonup	2		
		Moora	2
		Narembeen	2
Quairading	2		
West Authur	2		
		Yilgarn	2
		Bruce Rock	1
		Nungarin	1
Ravensthorpe	1		
Tambellup	1		
		Three Springs	1
York - -	1		

Table 3.Weighted frequencies of water deficiency declaration of shires or parts of shires in Western Australia, as the number of shire-years* in the 10 year period 1977/78 to 1986/87

Shires in the Great Southern, southern wheatbelt, and south-eastern wheatbelt		Shires in the northern, north-eastern,and eastern wheatbelt	
Dumbleyung	5.25		
Broomhill	5		
		Mt Marshall	4.75
Kent	4.5		
Woodanilling	4.5		
Katanning	4		
Lake Grace	3.75		
Kulin	3.5		
Wagin	3		
Cuballing	3		
Pingelly	3		
		Westonia	3
Wickepin			
		Koorda	2.5
		Mukinbudin	2.25
Kondinin	2		
Corrigin	2		
		Narambeen	2
Quairading	2		
		Yilgarn	2
West Arthur	1.5		
Brookton	1.5		
Beverely	1.5		
Gnowangerup	1.25		
Tambellup	1		
		Bruce Rock	1
Ravensthorpe	1		
		Nungarin	1
York	1		
		Moora	1
Kojonup	0.75		
		Three Springs	0.75

*For any one shire, the maximum number of shire-years in the 10 year period is 10..

Table 4. Weighted indices of water deficiency declaration of shires or parts of shires in Western Australia, calculated as the total number of sheep-years for which emergency water supply was required in the 10 year period 1977/78 to 1986/87

Shires in the Great Southern, southern wheatbelt and south-eastern wheatbelt			Shires in the northern, north-eastern wheatbelt		
Shire	Total Sheep number in shire* (thousands)	Index – sheep-years (millions)	Shire	Total Sheep number in shire* (thousands	Index – sheep-years (millions
Lake Grace	764	2.9			
Kent	583	2.6			
Dumbheyung	381	2.0			
Wagin	521	1.8			
Broomehill	356	1.8			
Kuhn	478	1.7			
Katanning	371	1.5			
Woodanihhing	314	1.4			
West Arthur	922	1.4			
			Mt Marshall	263	1.3
Pingelly	387	1.2			
Kojonup	1342	1.0			
Gnowangerup	795	1.0			
Wickepin	375	0.9			
Cubalhing	278	0.8			
Beverley	513	0.8			
Corrigin	375	0.8			
Kondinin	344	0.7			
			Narembeen	347	0.7
Quairading	341	0.7			
Ravensthorpe	640	0.6			
			Moora	618	0.6
Brookton	390	0.6			
			Yilgarn	275	0.6
			Koorda	174	0.4
York	379	0.4			
Tambehhup	370	0.4			
			Westonia	118	0.4
			Mukinbudin	154	0.4
			Bruce Rock	318	0.3
			Three Springs	338	0.3
			Nungarin	71	0.1

* Total sheep numbers at March 31, 1987 as reported by Australian Bureau of Statistics (1987).

Table 5 Weighted indices of water deficiency declaration of shires or parts of shires in Western Australia, calculated as average sheep numbers per hectare per year per shire for which emergency water supplies were required in the hO year period 1977/78 to 1986/87

Shires in the Great Southern, southern wheatbelt, and south-eastern wheatbelt			Shires in the northern, north-eastern, and eastern wheatbelt		
Shire	Area* (millions ha)	Index (sheep/ha per annum,)	Shire	Area* (millions ha)	Index (sheep/ha per annum)
Broomehill	0.11	1.64			
Woodanihhing	0.11	1.27			
Katanning	0.15	1.00			
Wagin	0.19	0.95			
Pingelly	0.13	0.92			
Cubahhing	0.09	0.90			
Dumbleyung	0.23	0.87			
Kent	0.38	0.68			
West Arthur	0.22	0.64			
Beverley	0.17	0.47			
Wickepin	0.20	0.45			
Brookton	0.14	0.43			
Lake Grace	0.73	0.40			
Kuhn	0.42	0.40			
Quairading	0.21	0.33			
Kojonup	0.31	0.32			
Tambellup	0.13	0.31			
Corrigin	0.26	0.31			
York	0.15	0.27			
GnowangeruK	0.41	0.24			
ondinin	0.37	0.19			
			Mt Marshall	0.69	0.19
			Westonia	0.21	0.19
			Narembeen	0.38	0.18
			Koorda	0.25	0.16
Ravensthorpe	0.41	0.15	Mukinbudin	0.29	0.14
			Moora	0.46	0.13
			Three Springs	0.25	0.12
			Bruce Rock	0.27	0.11
			Nungarin	0.10	0.10
			Yilgarn	0.86	0.07

* Total areas of agricultural establishments in 1983/84 as reported by Australian Bureau of Statistics (1985).

The weighted frequencies of water deficiency declaration of shires (as given in Table 3) have been combined with total sheep numbers in each shire in Table 4. These weighted indices are the total number of sheep-years in each shire for which emergency water was required during the 10 year period, and to the extent that total sheep numbers are an indicator of water needs in a shire, the ranking of these indices indicates the relative severity of water deficiency in the 32 shires in the period 1977/78 to 1986/87. This analysis takes no account of the size difference between shires.

The weighted indices presented in Table 4 have been combined with the total area of agricultural establishments in each shire in Table 5, to give another set of weighted indices which are average sheep numbers per hectare per year per shire for which emergency water supplies were required in the 10 year period 1977/78 to 1986/87. Because this index combines the frequency of water deficiency declaration with total livestock number and total area of agricultural establishments in each shire, it would appear to be a realistic index of comparative water deficiency between shires.

7. Discussion and Conclusions

Additional usable groundwater is unlikely to be found in the southern, south—eastern, eastern and north-eastern wheatbelt, and the creation of reliable on-farm water supplies in the known areas of frequent water deficiency will depend upon installing more farm dams and roaded catchments.

In the north eastern wheatbelt, despite significant usable groundwater being available on many farms, 75 per cent of all farms rely partly or wholly on surface water supplies. Due largely to the interaction of the effects of low and variable rainfall, high evaporation, and difficult soil conditions for dam and catchment construction, the available evidence indicates that the north-eastern wheatbelt is the most difficult district for establishing on-farm water supplies.

Although the southern and south-eastern wheatbelt has been declared water deficient more frequently in recent years than the eastern and north-eastern wheatbelt, the problem on the majority of farms in the southern districts could be overcome by application of known technology, for a lower total cost than in more northerly districts. Despite this, there are some farms with calcareous and saline soils in the “Lakes” districts, which have severe, although not insurmountable, water supply problems. These farms are estimated to constitute approximately 15 per cent of all farms in the south—eastern wheatbelt, and may require special consideration.

There are limited areas of cracking clay soils in districts such as Bindi Bindi, Dalwalhinu-Pithara and Ravensthorpe. Such soils are generally not suitable for construction of roaded catchments, and these districts may also require special consideration.

The level of adoption of proven and appropriate water conservation practices on farms is still very low and surveys done by the Department of Agriculture have shown great potential for water supply improvement on farms.

There is an urgent need for additional extension workers in farm water conservation and for extension of better surface water conservation techniques - such as roaded catchments, stable inlet structures, ring tanks and above-ground storage. More extension workers with knowledge of groundwater exploration and development would increase the effective utilisation of groundwater on farms.

It is known that investment in water supply did not keep pace with livestock numbers in the South Stirlings district in the l96Os and a similar trend has been observed in farm water supply in surveys in other districts in the l97Os. Farms generally appear to have insufficient capital invested in water supply, and farmers are often reluctant to spend money on maintenance of dams and catchments until after a period of water deficiency.

Department of Agriculture extension should aim to help farmers to plan more adequately for low rainfall years, and to be better managers of their water supply systems. We have concentrated largely on the basics of establishing supplies, and in the future we should give greater emphasis to operating and maintaining existing supplies.

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