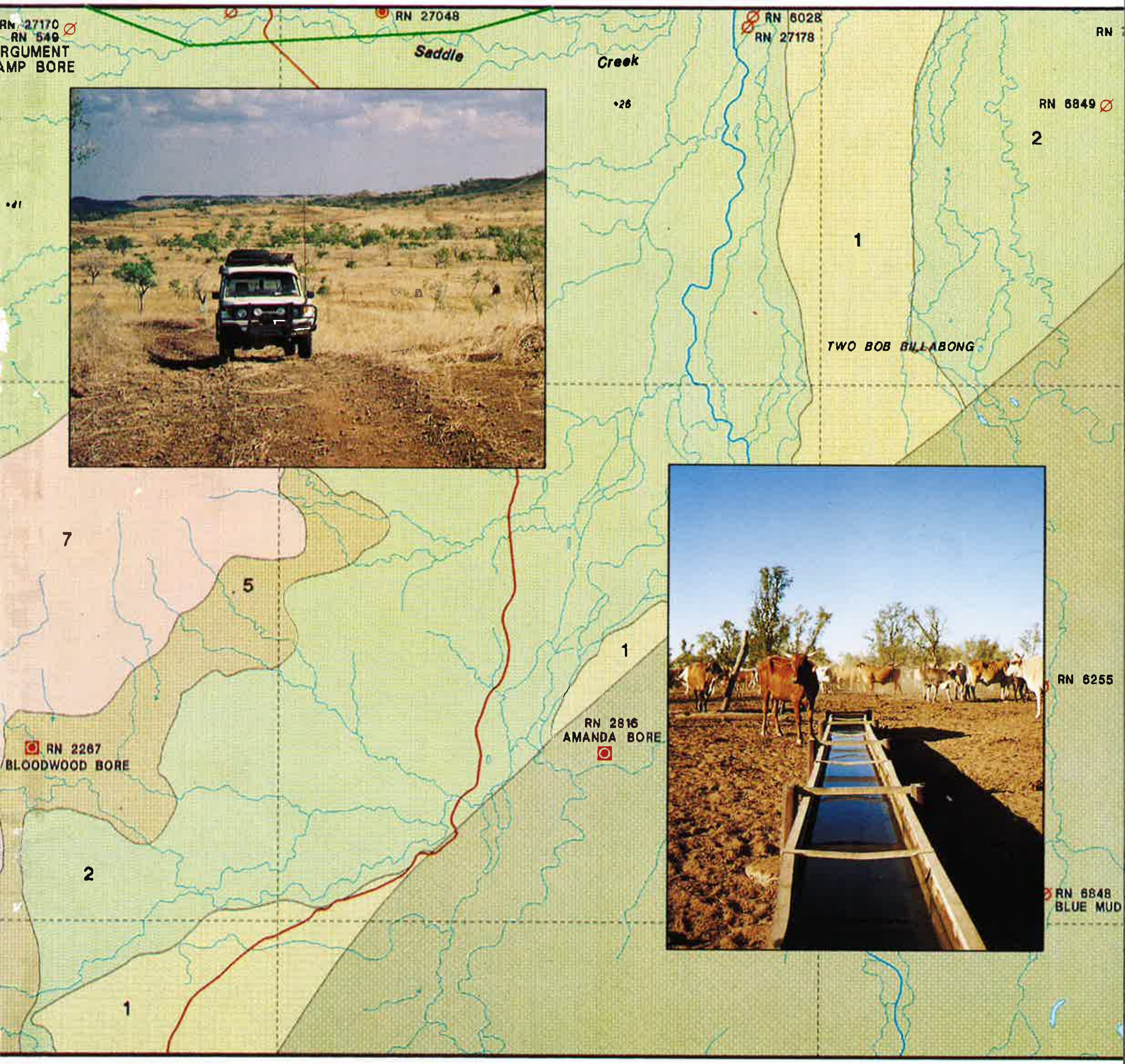
WATER RESOURCES SURVEY OF
THE WESTERN VICTORIA RIVER DISTRICT

WATER RESOURCES OF THE VICTORIA RIVER DISTRICT

Report #11/1998

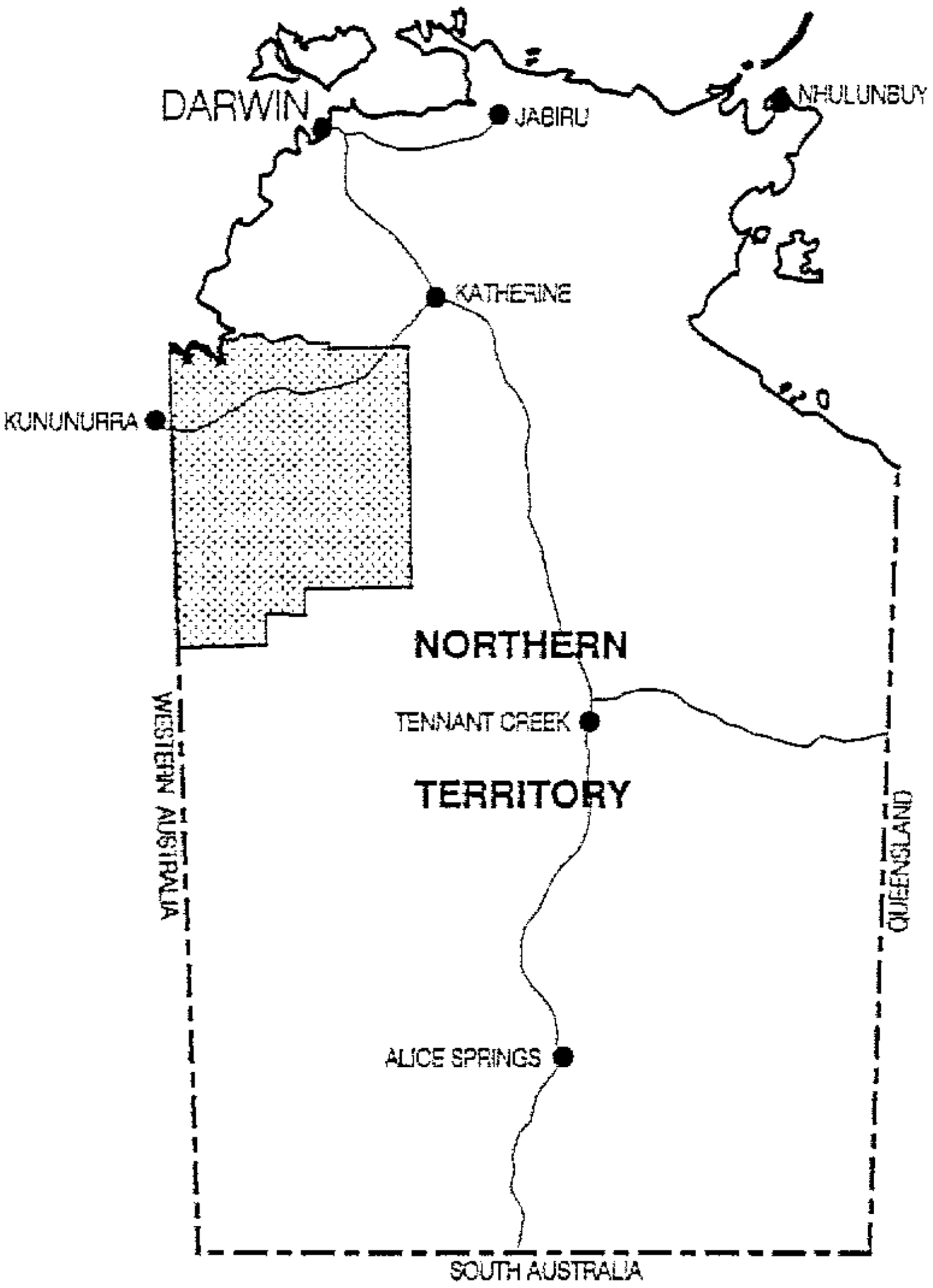


POWER AND WATER AUTHORITY

NATIONAL LANDCARE PROGRAM

DEPARTMENT OF LANDS PLANNING AND ENVIRONMENT
NATURAL RESOURCES DIVISION

WATER RESOURCES OF THE VICTORIA RIVER DISTRICT



REPORT 11/1998D
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DARWIN
AUGUST 1998

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SUMMARY

For most properties water availability is not a major limitation, rather it is the cost of developing a new supply which is the most important consideration. Bores provide the main water source in the Victoria River District (VRD) and groundwater supplies are adequate in most areas for stock watering. Natural surface waters such as waterholes and springs are used to a lesser extent but these sources are limited in number. Despite large surface water flows during the Wet, dams are relatively uncommon. More use of excavated tanks is recommended in suitable areas, although restrictions due to soil types and soil depths generally limits dam storage to a six to nine month stock water supply. Other types of storages such as embankment (gully) dams have the potential to hold water for longer periods but they are not recommended here because of the high maintenance required and the consequent risk of failure.

A number of environmental factors need to be considered in cattle station management in order to maintain the long term viability of the industry. These include soil erosion, weeds, alteration of the balance of native flora and fauna and water pollution. The location and use of water sources are key factors in this regard. Recommended ways of reducing these impacts are to fence off watering points and to make more use of pipeline networks to spread grazing uniformly over a greater area.

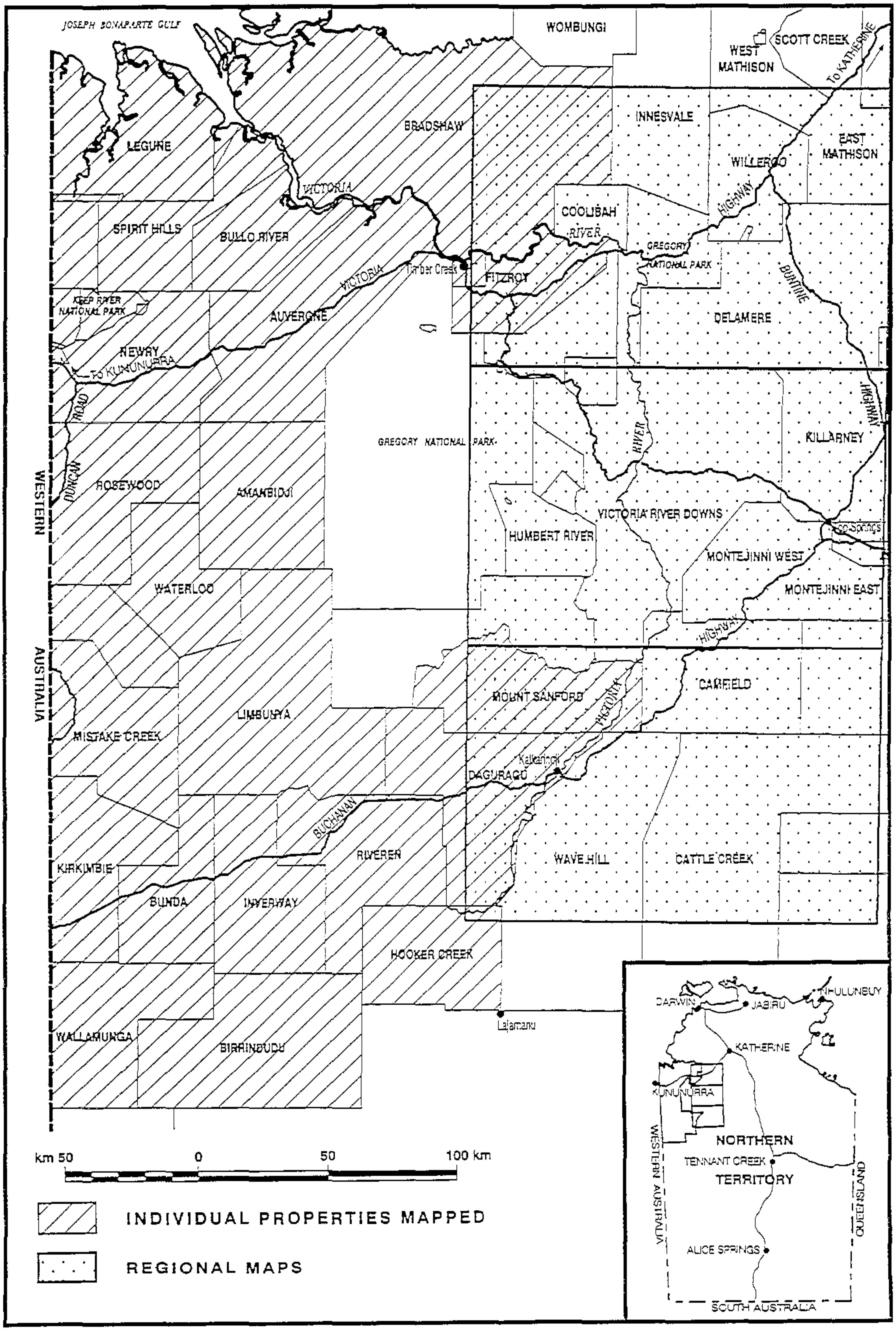
INTRODUCTION

The aim of this study is to map, describe and evaluate the region's water resources. The project was started in 1993 at the request of the Victoria River District Conservation Association (VRDCA) and it was funded jointly by Landcare, the NT Government and the VRDCA. It's purpose is to provide pastoralists and communities with water resource information that will assist with property planning.

The area studied covers approximately 120,000 km^2 and includes the Victoria River drainage basin in the far northwest of the Northern Territory (Figure 1). Beef cattle grazing on semi-natural rangelands is the dominant land use. Other uses include aboriginal living areas, National Parks and military training areas.

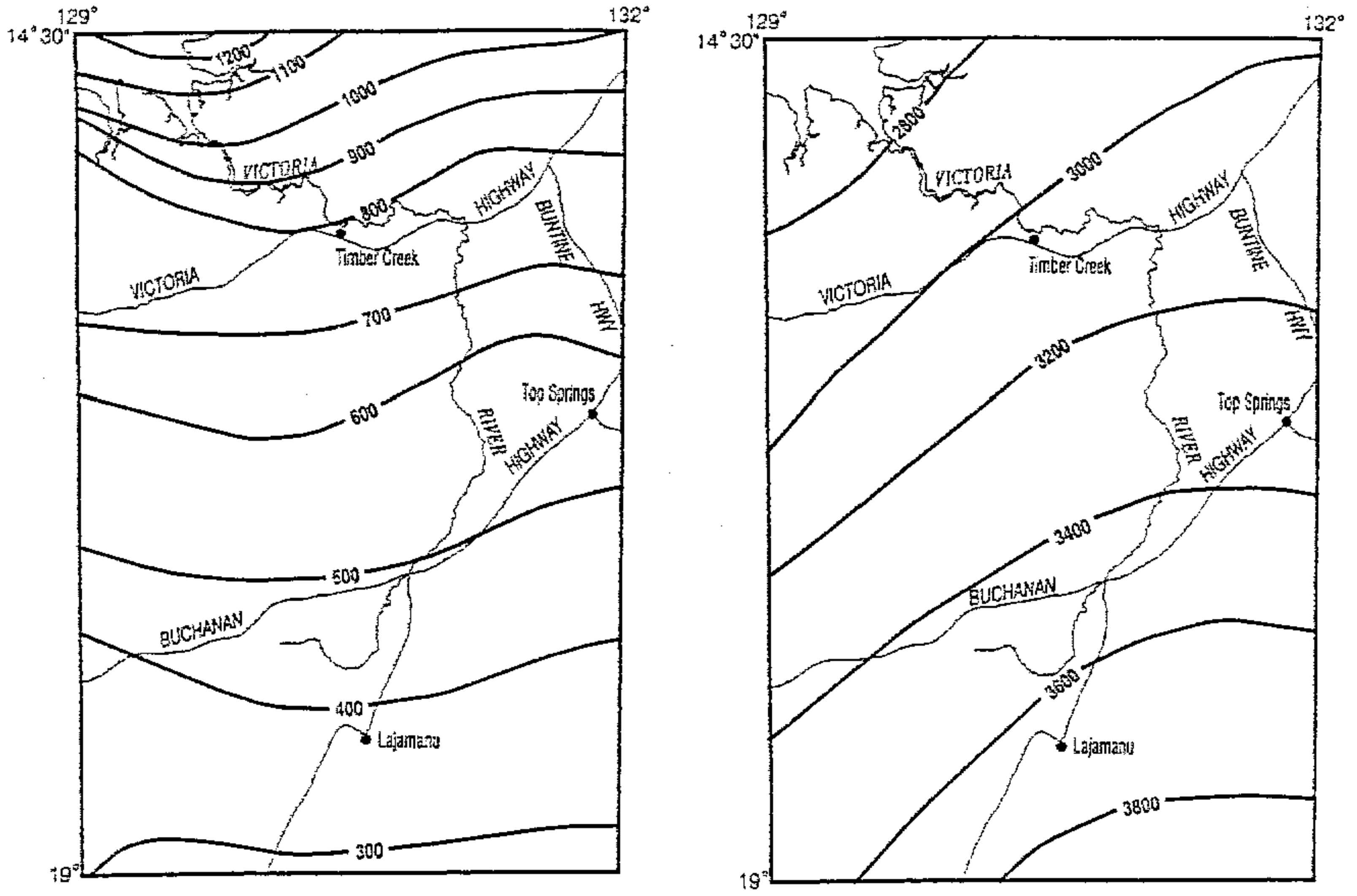
Timber Creek is the largest town in the district. Other settlements include Daguragu, Lajamanu and Top Springs. The nearest major population centres are Katherine to the east and Kununurra to the west.

The climate is hot, with rainfall restricted to the "Wet" monsoonal season from November to March. There is a north to south trend in the rainfall and evaporation, controlled by the distance from the coast (Figure 2). Average annual rainfalls vary from 800 mm in the north at the coast but are as low as 470 mm in the far south at Lajamanu. Rainfall events are commonly intense, either in the form of local thunder storms or widespread monsoonal events. Pan evaporation increases inland from 2800 mm at the coast to a high of 3700 mm in the south. Daily evaporation rates during the Dry season (April to October) are of the order of 7 mm.



LOCALITY MAP OF THE VICTORIA RIVER DISTRICT

Fig. 1



MEDIAN ANNUAL RAINFALL (mm)

AVERAGE ANNUAL PAN EVAPORATION (mm)

RAINFALL AND EVAPORATION

Fig. 2

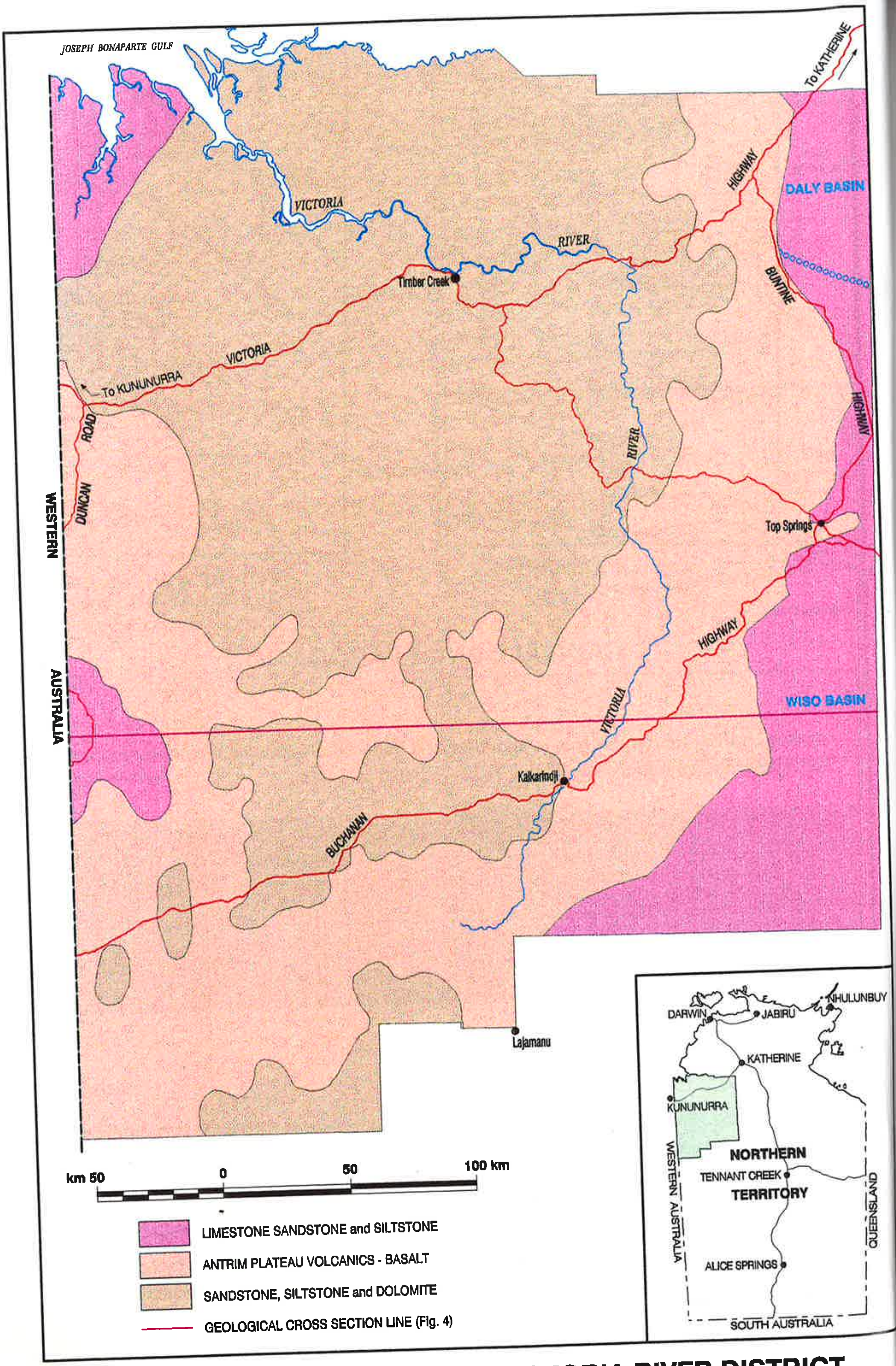
Average values for rainfall, pan evaporation and daily minimum and maximum temperatures for representative stations across the VRD are listed in Table 1.

	Annual Rainfall mm	Annual Pan Evaporation mm	July Avg.Daily Maximum Temp °C	July Avg.Daily Minimum Temp °C	November Avg.Daily Maximum Temp °C	November Avg.Daily Minimum Temp °C
Bradshaw	854	2900	30.3	12.9	38.5	25.3
VRD	620	3300	28.9	10.6	38.6	23.9
Lajamanu	471	3700	25.2	7.8	37.9	22.9

TABLE 1 Average climatic figures.

GEOLOGY

Rock type and geological structure are some of the main factors influencing groundwater occurrence and the location of springs. The suitability of an area for dams is also partly determined by these. The distribution of the major geological units are shown in Figure 3 and their relationships with each other with depth are shown on the cross-section in Figure 4. The oldest rocks in the district are sandstones, siltstones and dolomites of Pre-Cambrian age (older than 545 million years). These outcrop in the central areas, with resistant sandstones forming ranges and softer rocks such as siltstones forming the valleys. The sedimentary rocks are in alternating layers that have been tilted at low angles, normally less than five degrees. Extensive jointing and some faulting was created when the rocks were folded.



REGIONAL GEOLOGY OF THE VICTORIA RIVER DISTRICT

Fig.

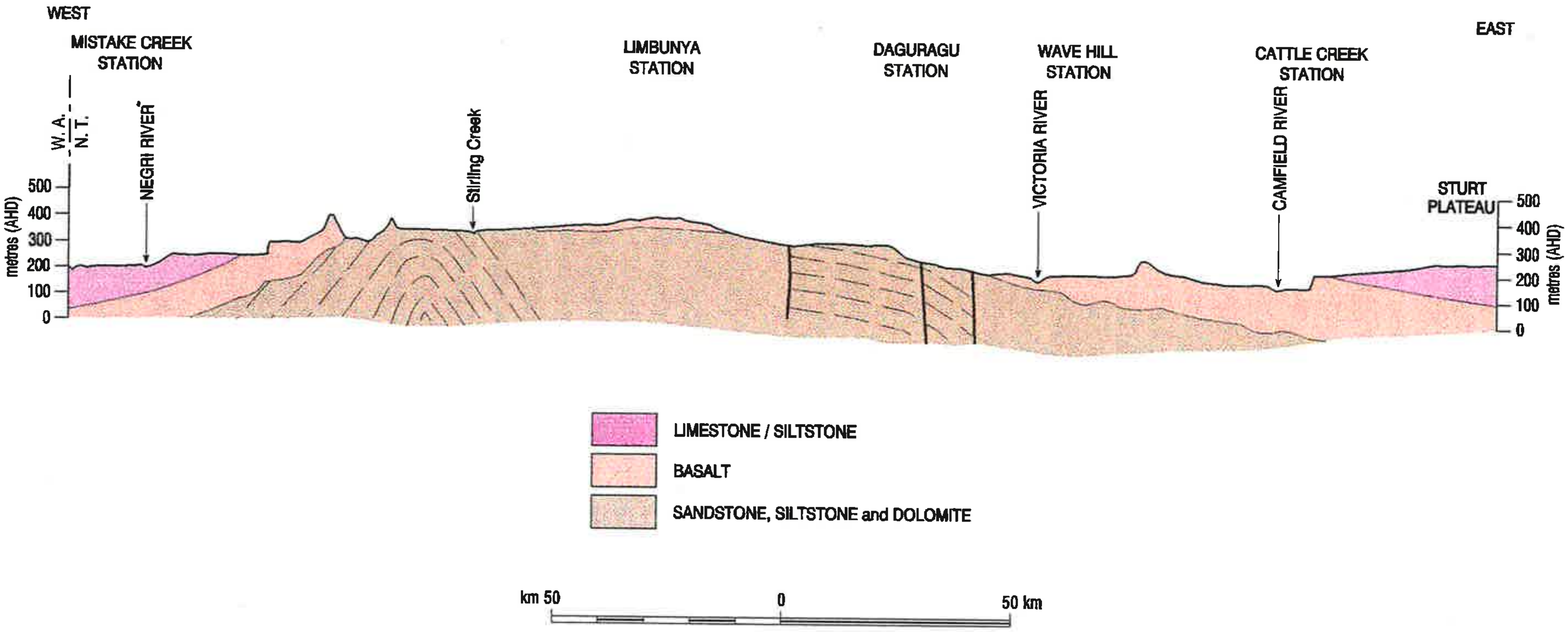


Fig. 4

GEOLOGICAL CROSS SECTION ACROSS THE CENTRAL VRD

See Fig. 3 for location of the section

Overlying the Pre-Cambrian rocks in the western, eastern and southern areas are widespread basalts of Cambrian age (490 to 545 million years), known as the Antrim Plateau Volcanics. These are up to several hundred metres thick and accumulated as numerous individual lava flows stacked on top of each other. A pre-existing, undulating land surface was buried by the basalt.

The Wiso and Daly Basins, large sedimentary basins containing flat lying limestone and siltstone border the eastern side of the VRD. They in turn overlie the Antrim Plateau Volcanics and are of Cambrian and Ordovician age (545 to 434 million years). An outlier of the main basin occurs on Mistake Creek on the Western Australia border. Sandstone, conglomerate, shale and limestone of similar age are found on the coast on Legune. Following this period of deposition the whole area was warped into a broad north south trending arch structure with the oldest rocks exposed in the central area and progressively younger rocks to the east and west (Figures 3 and 4).

Since the Ordovician there has been little accumulation of sedimentary rocks. A thin deposit of sandstone and claystone formed in the Cretaceous (65 to 140 million years) and remnants of it now cap the limestones of the Wiso and Daly Basins. Uplift and erosion of the area began soon after the Cretaceous and that regime continues to the present. The Victoria and Ord Rivers are actively eroding southwards and eastwards.

Alluvial deposits are only minor in extent and are mainly found near the coast. Lake deposits formed in the internally draining parts of the southern VRD and these are preserved as silcrete beds beneath the black soil plains of Birrindudu and Wallamunga.

LANDFORM AND DRAINAGE

The Victoria and Ord catchments have been strongly dissected. Landforms largely reflect the underlying rock types and geological structure. For example basalt areas are mostly hilly to gently undulating with occasional flat topped prominent hills. Pre-Cambrian sedimentary rocks on the other hand develop rugged ridge and valley topography due to differential weathering along hard and soft strata. The Pinkerton, Newcastle and Stokes Ranges and their intervening valleys are typical examples. The hills are usually capped by hard sandstone. In the northern VRD there is a prominent northeast - southwest structural trend that is reflected in the alignment of the ranges and valleys. Similarly a dome structure has resulted in a near circular ridge and valley pattern centred on the Fitzgerald Range. The ranges reach a maximum elevation of 370 metres above sea level on Spirit Hills.

To the east the Victoria River is cutting back into the Sturt Plateau a flat to gently undulating area developed on Cambrian Limestone. Drainage on the plateau is poorly defined, particularly towards the south where sand dunes blanket the landscape. Ground elevations average 250 metres above sea level.

The rivers are gradually eroding their way southwards dissecting an ancient flat landscape. This old landscape is typically gently undulating, capped by a laterite soil profile and is drained by inland flowing rivers. Remnants of it are preserved in the southern VRD from Wallamunga to Inverway. Extensive black soil plains flank the streams and ground elevations average 400 metres above sea level.

CURRENT WATER USAGE

Stock watering is the main water use in the VRD. Groundwater is the primary source but surfacewaters are used particularly during the wet season and the early part of the Dry season. There are some 600 stock bores currently utilised (Figure 5a) with a typical spacing of about 12 kilometres and an average pumping rate of 2 l/s. The total volume of groundwater extracted is of the order of 3600 million litres/year. Considering the large area involved this is only a minor volume, amounting to only 0.005% of the annual rainfall. Surfacewaters used for stock are mainly from waterholes. Excavated tanks and dams are relatively uncommon with about only 90 throughout the VRD (Figure 5b). Stations such as Bradshaw and Amanbidji, have opted for dams because they overlie rocks which are unfavourable for groundwater. Homestead water supplies are predominantly groundwater and the volumes extracted are minor in comparison to stock usage.

WATER RESOURCE MAPS

The map accompanying this report was compiled from water resource maps of twenty one individual properties in the western VRD, mostly at 1:100,000 scale and from three broad scale groundwater maps covering the Delamere, VRD and Wave Hill 1:250,000 mapsheets (Figure 1). The basic information used to make it includes geology, topography, land unit and land system mapping, bore data, climate records, aerial photography and satellite imagery. Field surveys were carried out to check locations of water sources, to sample water and to confirm soil and rock types.

The main features shown on the main map and the two side maps are now described:

WATER SUPPLY OPTIONS MAP

This is a guide to the most likely options for developing water supplies. Seven categories are shown:

- unsuitable for bores or surfacewater storages due to rugged terrain.
- unsuitable for bores or surfacewater storages due to poor groundwater prospects and unsuitable soils.
- suitable for bores only
- suitable for surfacewater storages but not for bores
- locally suitable for surfacewater storages but not for bores
- suitable for bores and surfacewater storages
- suitable for bores and locally for surfacewater storages

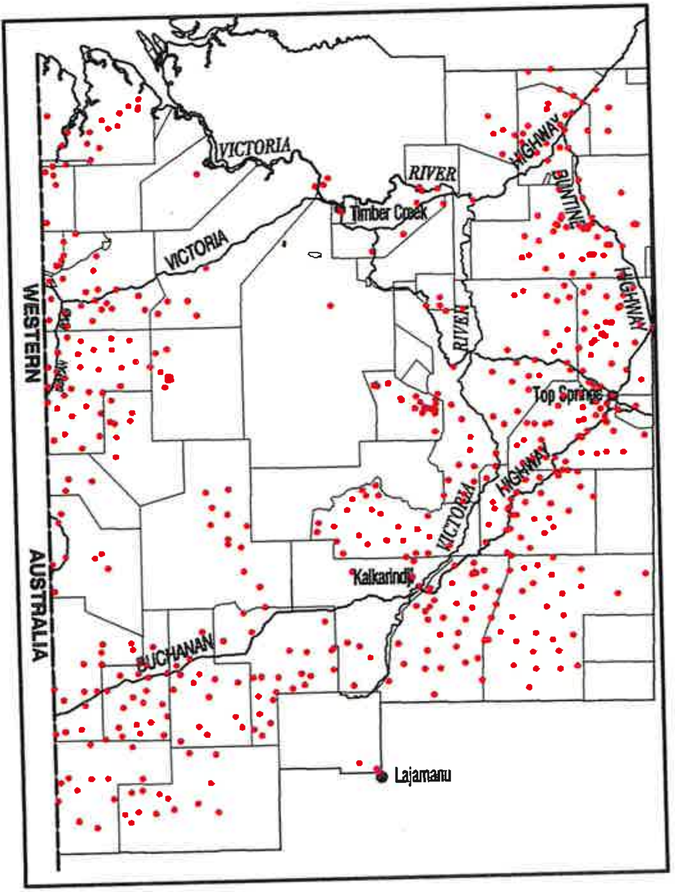
Note that the map does not show any options relating to individual natural waterholes or springs.

GROUNDWATER MAP

The groundwater map shows generalised yield and water quality characteristics. The distribution of the main aquifer types can be seen on the smaller side map. The overall pattern indicates that stock supplies can be obtained from selected sites in most areas. Notable exceptions are those underlain by siltstone, such as the Angalarri and Baines Valleys on Bradshaw and Auvergne.

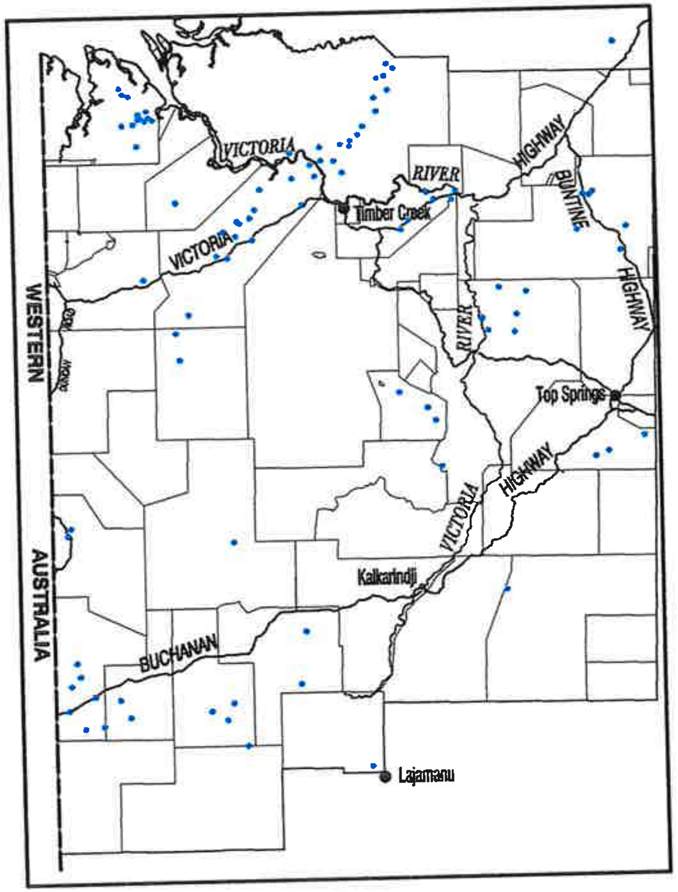
Yield

Three classes of bore yield have been mapped; less than 0.5 L/s, 0.5 to 5.0 L/s and more than 5.0 L/s. These represent typical sustainable yields which could be expected from bores sited using geological and local knowledge. Standard bore construction with 152 mm slotted casing is assumed.



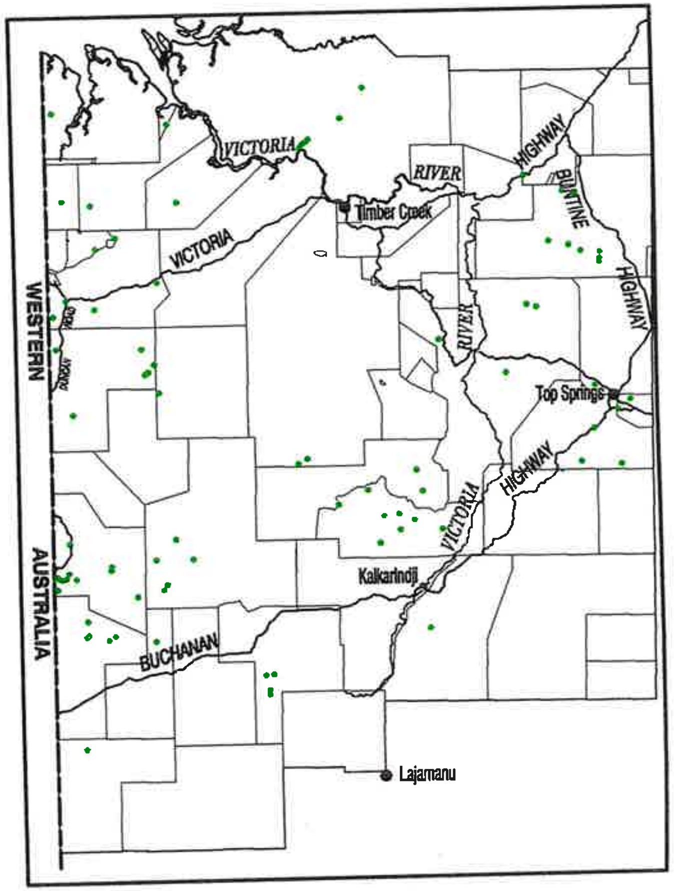
PRODUCTION BORES

Fig. 5a



DAMS

Fig. 5b



SPRINGS

Fig. 5c

Note : Only the major dams and springs are shown

BORES, DAMS AND SPRINGS

Fig.

Note that sustainable yield of a bore is generally less than the reported airlift yield because the latter is only determined during a short duration test. Natural variation in the properties of rocks means that a certain variation in bore yield within an area will also occur. For example Figure 6a shows that within a zone mapped as 0.5 to 5.0 L/s, a percentage of bores will have higher yields and a percentage will be lower, but most will fall inside the limits.

Yields Less than 0.5 L/s
It is generally considered uneconomic to construct and equip a stock bore with a yield of less than 0.5 L/s. In the past however, yields as low as 0.1 or 0.2 L/s were considered satisfactory and bores were equipped with windmills.

Yields between 0.5 and 5.0 L/s
An optimum supply for a single watering point is about 1.5 to 2.0 L/s. Most stock bores are only equipped to pump that amount, even if they are capable of higher yields. Bores with higher yields have the potential to supply several remote watering points via pipeline networks.

Yields more than 5.0 L/s
Bores with yields in this range may have sufficient capacity to supply multiple watering points and for limited irrigation. No aquifers capable of supplying groundwater for major irrigation have been identified.

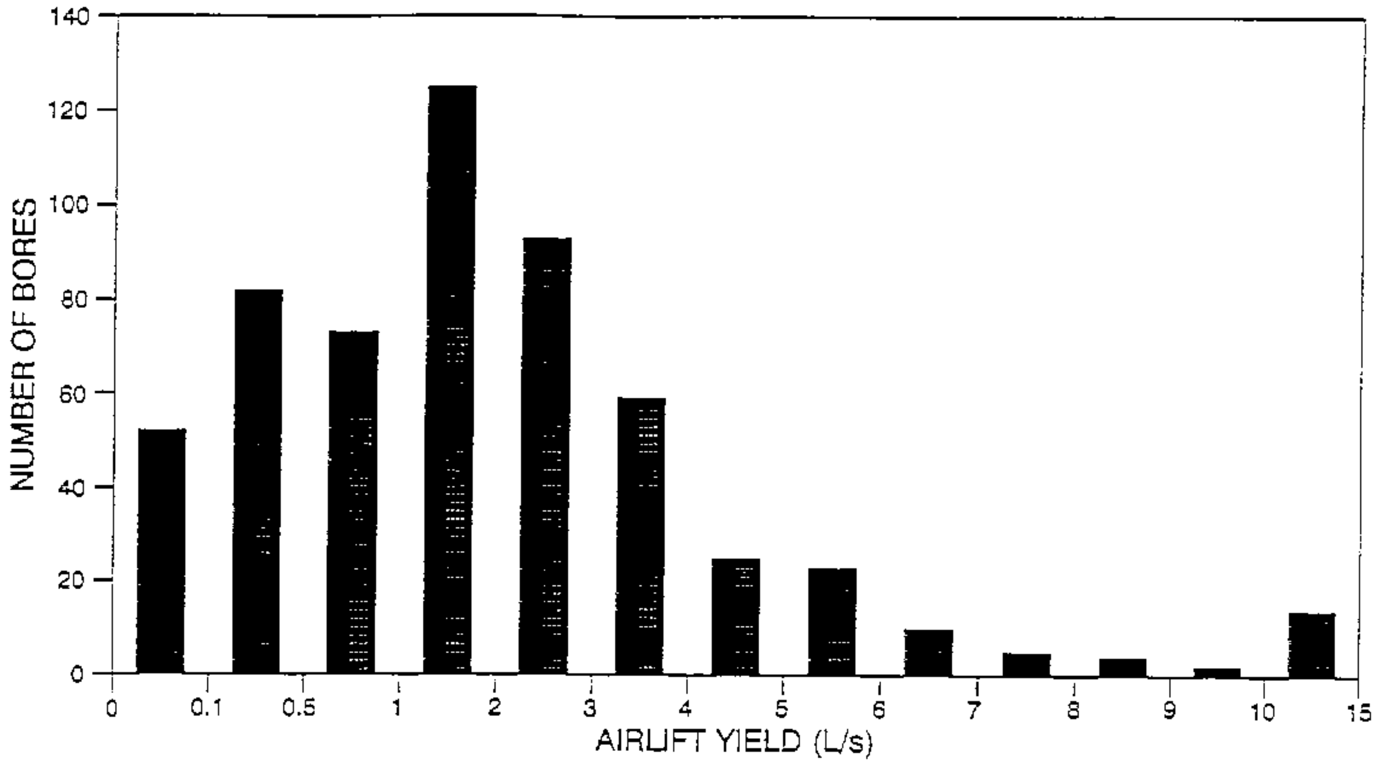
Water Quality
Two classes of groundwater quality are shown on the map; suitable for stock and unsuitable for stock. Total Dissolved Solids was used as a measure of water quality and a value of 10,000 mg/L marks the limit between the two zones.

SURFACE WATER MAP
The surfacewater map shows suitability for surfacewater storages. Three categories have been mapped, suitable, locally suitable and unsuitable. A general description of each zone is given below:

Suitable for excavated tanks
These are the most prospective areas and are extensive plains with black clay soils. Major occurrences include the coastal and alluvial plains on Legune and Spirit Hills and alluvial plains on Auvergne, Bradshaw, Wallamunga, Birrindudu, Bunda, Kirkimbi and Inverway. Most existing excavated tanks are situated on this type of country. The clay soils seal the tanks well and they are generally deep enough to provide adequate depth of excavation. In the case of Auvergne and Bradshaw the soils are relatively thin but they are underlain by weathered shale which is soft enough to be ripped and which also forms an impervious base.

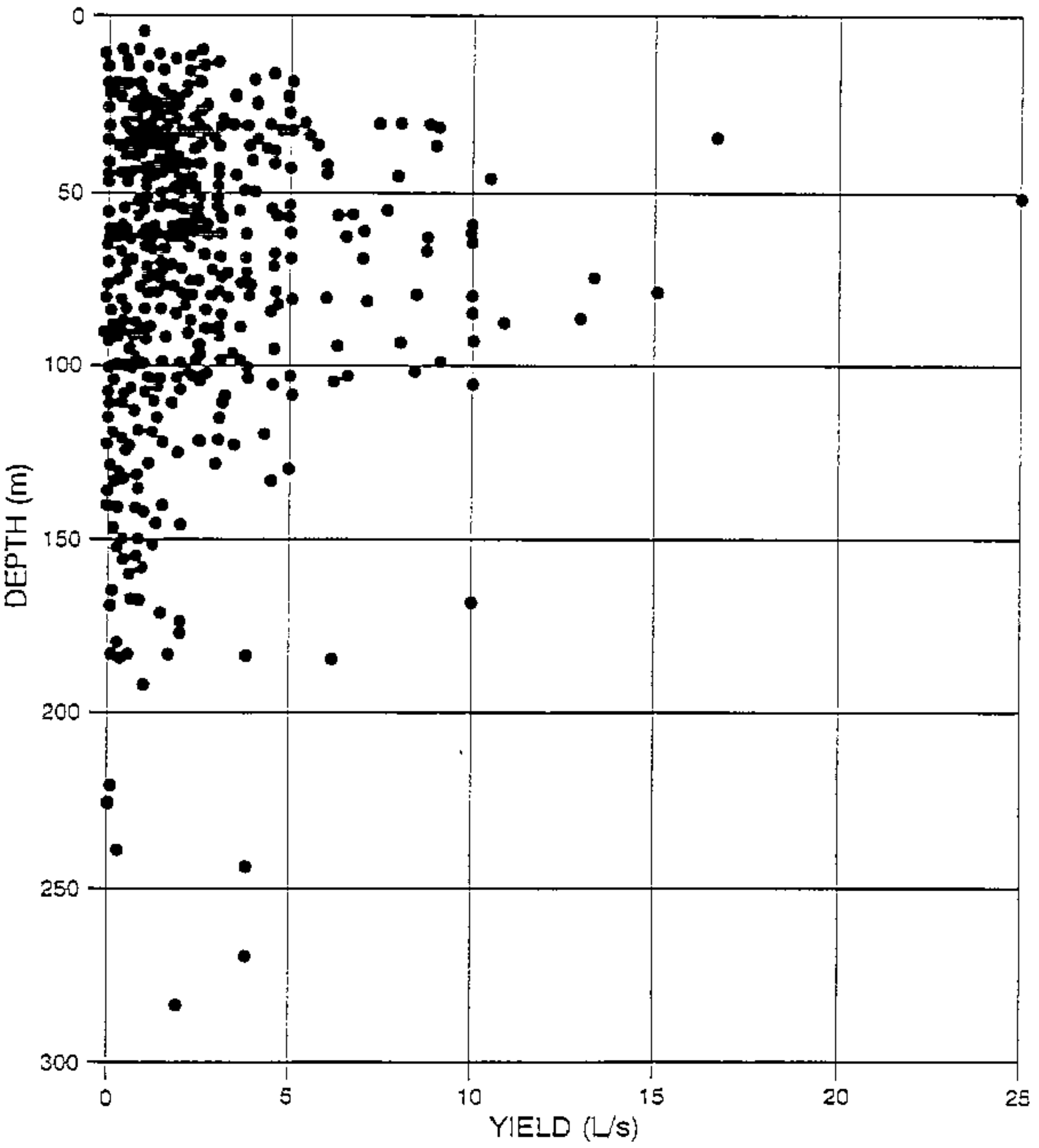
Although these areas are classed as suitable, soil depth and type can vary markedly so site investigations need to be carried out before any excavation begins.

Locally suitable for excavated tanks
Two main types of area are included in this category; flat to undulating areas of black clay soil on basalt and narrow alluvial plains. The depth and type of soil and the nature of the material below the soil tend to be more variable in these environments, resulting in reduced prospects for successful excavated tanks. The clay soils on basalt are often less than two metres deep and the underlying rock is too hard for excavation. Dam sites will be restricted



FREQUENCY OF AIRLIFT YIELDS,
BASALT AQUIFER

Fig. 6a



DISTRIBUTION OF YIELDS WITH DEPTH,
BASALT AQUIFER

Fig. 6b

to local areas where the clay soil is of sufficient depth. In the narrow alluvial areas soils can vary from sandy through to clayey and this together with soil depth governs the site suitability.

Unsuitable for excavated tanks
Areas classified as unsuitable have either one or a combination of the following factors: steep slopes, thin soils, porous soils and subsoils or shallow hard bedrock which is not economic to excavate. They include areas of outcropping bedrock, rugged hilly country, laterite plateau and sand dune country.

GROUNDWATER

The main source of stock water in the VRD is groundwater. It is normally extracted with bores, typically constructed with 150 mm slotted steel or PVC casing. The water is pumped to a tank such as a turkey nest or steel tank and then gravity fed to one or more troughs (Plates 1 and 2). Down hole pumps powered by diesel motors are the commonest setup, with windmills gradually being phased out.

Moderate to small quantities of groundwater are widely available, but on a local scale it is often unevenly distributed due to the nature of the aquifers.

AQUIFER TYPE

Five aquifer types have been recognised; fractured and weathered rocks, unconsolidated sediments, porous sedimentary rocks and fissured & cavernous rocks.

Unconsolidated sediments
In this type of aquifer, water is stored in the spaces between the sand grains. Aquifers consisting of unconsolidated alluvial sands and gravels are found as isolated patches, adjacent to the major rivers. Prominent occurrences include those along the Keep River on Spirit Hills and Legune, along the Victoria River from Timber Creek to Coolibah, along the Wickham River at Yarralin and on the West Bains River on Waterloo and Auvergne. Aquifer depths vary between 6 and 30 metres and typical yields are 1.5 L/s. The thickness and extent of the sand deposits varies from area to area. The Keep River deposits are the most extensive, filling a buried valley some 8 kilometres wide by 40 kilometres long. The sands range up to 30 metres in thickness and can produce yields of up to 10 L/s. Elsewhere alluvial aquifers are thin, limited to small, isolated occurrences and have only minor groundwater potential.

Sedimentary rocks with appreciable intergranular porosity
This is a similar type of aquifer to the previous category but the sand grains are cemented together to form sandstone. They still retain the pores between the grains and have the capacity for large storage and high yields. There are two main occurrences of such aquifers; one on Mistake Creek and another on Legune and Spirit Hills. Both are soft sandstones which form extensive aquifers. On Legune where many bores tap the aquifer, water is encountered at depths between 6 and 36 metres with an average airlift yield of 2.0 L/s. Standing water levels are shallower than 30 metres. Yields in excess of 10 L/s could be expected if bores were drilled deeper and if stainless steel screens were used instead of slotted casing. Oil exploration bores indicate that sandstone extends from the surface to depths of several hundred metres, where it is presumably still water bearing. The sandstone on Mistake Creek has only been drilled at two sites but appears to have similar characteristics to that at Legune.

Fissured and cavernous rocks

An extensive aquifer consisting of limestone occurs along the eastern side of the VRD. It forms the western margin of a large sedimentary basin which overlies the basalt, sandstone, siltstone and dolomite that outcrops to the west. An outlier of the main basin occurs on the West Australian border on Mistake Creek.

Limestone is prone to slowly dissolve in water, so groundwater moving through fractures eventually enlarges them into fissures and even caverns. The resulting aquifer is extensive, has a large storage capacity and supports high yielding bores.

Located on the edge of the sedimentary basin, the limestone is relatively thin, so yields are expected to be lower than those to the east of the map. The median airlift yield for limestone bores is 2.1 L/s, relatively low because most stock bores only penetrate the top of the aquifer. Yields of between 5 and 15 L/s should be obtainable if bores were to be drilled deeper. Standing water levels are less than 30 metres in the northern part of the map and deepen to between 30 and 90 metres in the south, around Cattle Creek Station.

Fractured and weathered rocks

Fractured rock aquifers make up the bulk of aquifers in the VRD. Groundwater occurs in networks of minute fractures and aquifers tend to be localised along zones where fracturing is more intense, such as faults. Basalt, sandstone, siltstone and dolomite are typical rocks in which these aquifers are developed. Widespread aquifers are present in places where an upper zone of weathered rock is well developed, such as in basalt on Birrindudu and Wallamunga. Elsewhere the degree of interconnection of aquifers varies, depending on the amount of fracturing.

Groundwater has been located at depths ranging down to 250 metres but average depths are about 60 metres. Fractures tend to be narrower with increasing depth, due to the lessening influence of chemical weathering and bore yields tend to decline. Figure 6b illustrates this with a plot of airlift yield against bore depth for all bores known to be drilled into basalt. At depths greater than 100 metres, yields tend to be low. Aquifer depth is also controlled by position in the landscape, for example a bore drilled on top of a hill is likely to strike water deeper than one situated on a nearby valley floor. Similarly standing water levels in bores tend to be shallower in lower country.

Yields obtained from the fractured rock aquifers are relatively low. The median airlift yields for the various rock types are; basalt 1.5 L/s, sandstone 2.0 L/s, dolomite 1.6 L/s and siltstone 0.5 L/s. An important aquifer on stations such as VRD and WaveHill is sandstone, lying beneath basalt at depths of up to 150 metres. Water is normally struck in the upper 20 metres of the sandstone, in a "fossil" weathered horizon.

The aquifer type "Fractured and weathered rocks with minor groundwater resources" as shown on the Groundwater map represents fractured rock aquifers with yields less than 0.5 L/s. They mainly comprise siltstone but in some areas such as Riveren, dolomite is also included.

WATER QUALITY

The great majority of VRD groundwaters are fresh and suitable for stock (Figure 7). Saline groundwaters are generally restricted to areas adjacent to the coastline or to tidally influenced streams. A minor area of saline water was mapped on the southern edge of the VRD on Birrindudu and Wallamunga. That occurrence together with an area of marginal quality water (not shown on the map) on Cattle Creek and Camfield are thought to be due to restricted surface drainage in the recent geological past. Evaporation in former lakes and floodouts led to a gradual build up of salt with the saline water accumulating in the underlying aquifers.

The only other aspect of water quality which may limit stock water use is fluoride. Up to five percent of all the equipped stock bores have fluoride contents in excess of the recommended limit of 2 mg/L. Most of these are less than 3 mg/L but veterinary advice should be obtained.

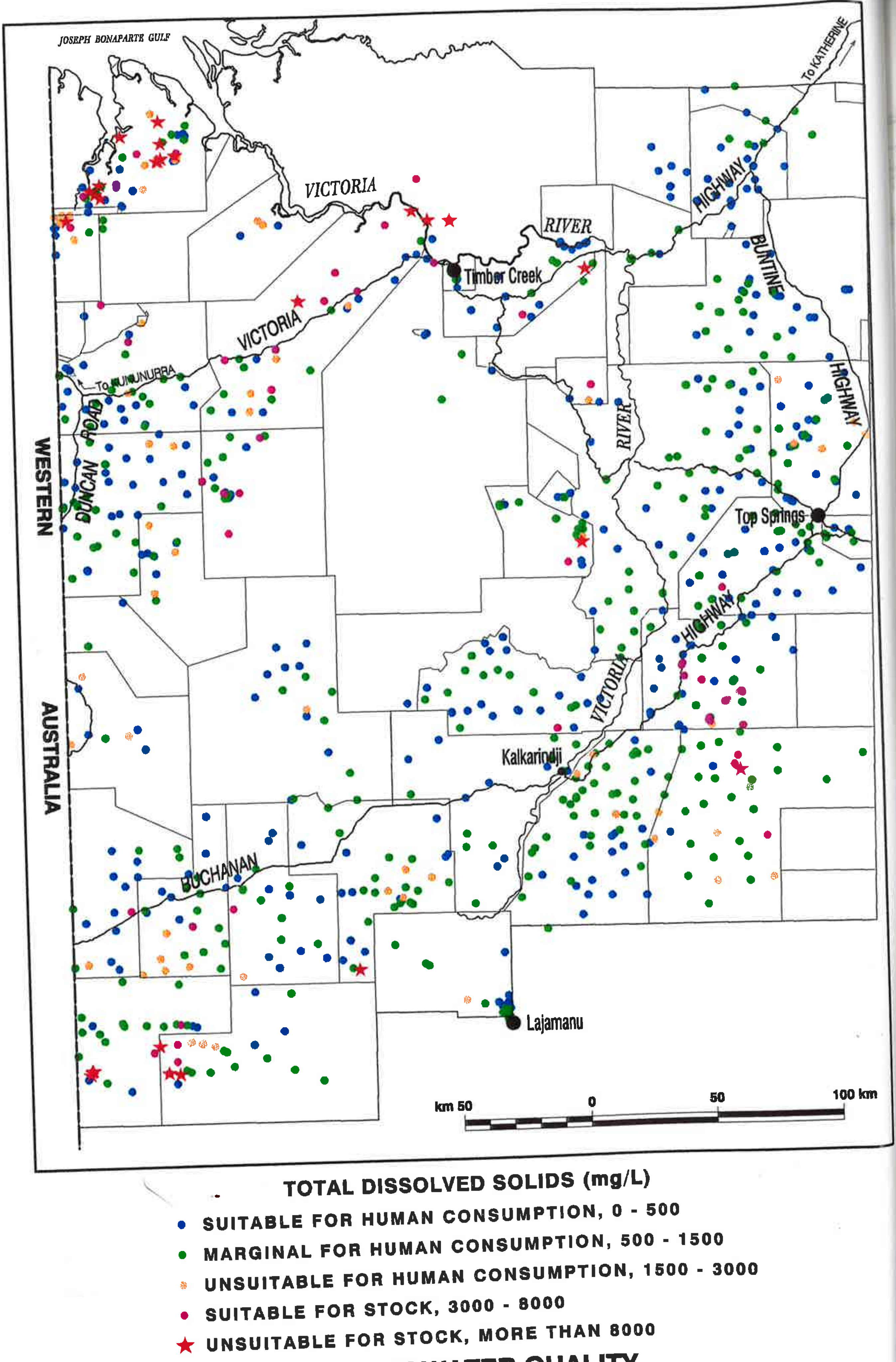
THE GROUNDWATER SYSTEM

The groundwater system consists of water seeping into the ground, moving slowly through the aquifers and eventually discharging to the surface. It can be likened to a bucket with a hole in its base and into which water is poured from time to time. A balance will be reached where the water level in the bucket only varies within certain limits determined by the amount and frequency of water going in, the size of the bucket and the size of the hole. Similarly in nature, rain recharges the aquifers during the Wet causing water levels to rise, while in the Dry the levels fall. Throughout the year groundwater flows through the aquifers under the influence of gravity and eventually discharges to the surface at springs, commonly situated at low points in the landscape. Groundwater can also leave the aquifer in places where deep rooted vegetation taps the watertable. Those factors together with the extent of the aquifer and its hydraulic properties determine how deep the water levels will be and how they will fluctuate.

If rainfall is low, recharge will be small, water levels will rise less and discharge will be reduced. On the other hand high rainfall will result in increased recharge, higher water levels and greater spring discharges. Although rates of flow are normally slow (eg. centimetres to a few metres per year) groundwater is rarely static.

Various studies were carried out as part of this project aimed at better understanding the various parts of the groundwater system. At Rosewood two monitoring stations were set up and groundwater levels in a basalt aquifer, rainfall and evaporation were measured continually for four years. Details of the study and its findings are included in Technical report18/1998D (*1). In another study naturally occurring isotopes of carbon, hydrogen and oxygen were analysed in water samples from bores, springs, streams and rain. Details can be found in Technical report 17/1998D (*2). These studies together with observations made on the chemistry of the major dissolved salts in groundwaters have led to several main conclusions:

- The isotopic composition of groundwaters fall within the same range as the heaviest rainfall events which occur at the peak of the Wet. Those events therefore constitute the main recharge source. Observations made at the Rosewood monitoring site support this with recharge only occurring when weekly rainfall is more than 100 mm. Early and late wet season rains on the other hand are of lesser importance.
- Isotopic composition of groundwaters together with their general low salinities indicates



GROUNDWATER QUALITY

Fig. 7

that recharge waters undergo relatively little evaporation before they reach the watertable. This means that freestanding water bodies such as waterholes are not major recharge sources and infiltrating waters have a short residence time in the soil. Recharge occurs by direct seepage of rainwater in areas where aquifers are exposed at the surface or by seepage through stream beds.

- Radiocarbon dates obtained for groundwaters are all relatively young. Most are less than fifty years old and the oldest was only 3000 years, suggesting that the residence times for groundwater in the aquifers from recharge are generally short. This is probably a reflection of the limited storage of the fractured rock type aquifers of the VRD. The water level record from the Rosewood bores also suggests limited aquifer storage capacity.
- Estimates of recharge have been made from several sources. Long term average values were obtained by comparing chloride concentrations of groundwaters with those of rainwater. Values of 14 mm and 8 mm in the northern and southern VRD respectively are considered to be of the correct order of magnitude. On a more local scale analysis of the Rosewood data indicates that annual recharge can vary from nothing to about 40 mm depending on the seasons rainfall.

SURFACEWATER

There are numerous surface water sources and storages in the region. Natural sources include waterholes, lakes and springs. Various types of dams have been constructed including excavated tanks, ring tanks and embankment dams. Dams are relatively uncommon and tend to be built in those areas where groundwater is difficult to obtain. Waterholes are the most widely used natural water source.

WATERHOLES AND LAKES

Waterholes occur throughout the region in all of the major rivers but also in medium sized streams and creeks. Most of the major rivers, for example the Victoria, Negri and East Baines Rivers and Swan Creek normally flow for about four to six months of the year. Stirling Creek flows for more than six months. For the balance of the year, they break up into chains of waterholes which last for varying periods depending on their depth and whether or not they are spring fed. Even shallow ones may be permanent if they are supplemented by spring flows, examples include Swan Creek Waterhole on Limbunya and Lowies Waterhole on Daguragu. Some waterholes particularly those on the major rivers are permanent but most are seasonal.

Waterholes form where there is a watertight rock base and where there is a rock bar acting as a dam. The Bulla community for example obtains its water supply from a waterhole with a siltstone base in the East Bains River. In the more rugged country, gorges are often the sites of long deep waterholes such as in Bullo River and Jasper Gorges. They also form on alluvial plains where impermeable clay rather than rock, forms the base and where depressions have been scoured in the channel. Lagoons or billabongs are depressions in the beds of abandoned or partly abandoned river channels. Ring Lagoon on Auvergne for example is an abandoned meander of the Bains River.

Only a few small lakes are found in the VRD, notably Lake Nongra on Birrindudu and Inverway, Watties Lake on Wallamunga, Leslie's Lake on Bullo River and an unnamed lake on Legune near Bundaburg Bore. All of these are formed on alluvial plains and are too shallow to be permanent. The most extensive of these, Nongra Lake becomes brackish as it dries up.

Waterholes vary in size, depending on the size of the stream. In major streams immediately after an average wet, waterholes can be a kilometre or more long and three or more metres deep. As an example Blackgin Waterhole located in Blackgin Creek, a medium size creek on Mount Sanford, lasts till the end of the Dry. It fills during an average Wet and when flow ceases it has a maximum depth of about 3 metres is 40 metres wide and about 600 metres long. The total storage capacity is about 59 Megalitres, sufficient to serve 350 head of cattle with 90% reliability on a daily basis from April to December. Waterholes in smaller streams have typical dimensions of 2 to 2.5 metres deep, 25 metres wide, and 100 metres long. These smaller ones can only support about 100 head of cattle over a three month period on a daily basis, depending on the catchment size and depth.

Waterholes in accessible areas are generally utilised for stock whereas many in rugged country are not. Few waterholes are fenced, and cattle drink directly from them. In order to use the water more efficiently and reduce erosion and siltation it is recommended that waterholes be fenced and stock water regulated through turkey nests or steel tanks. Waterholes should generally not be deepened, as it could disturb the water retaining regime and in many cases sediment would rapidly fill the excavation.

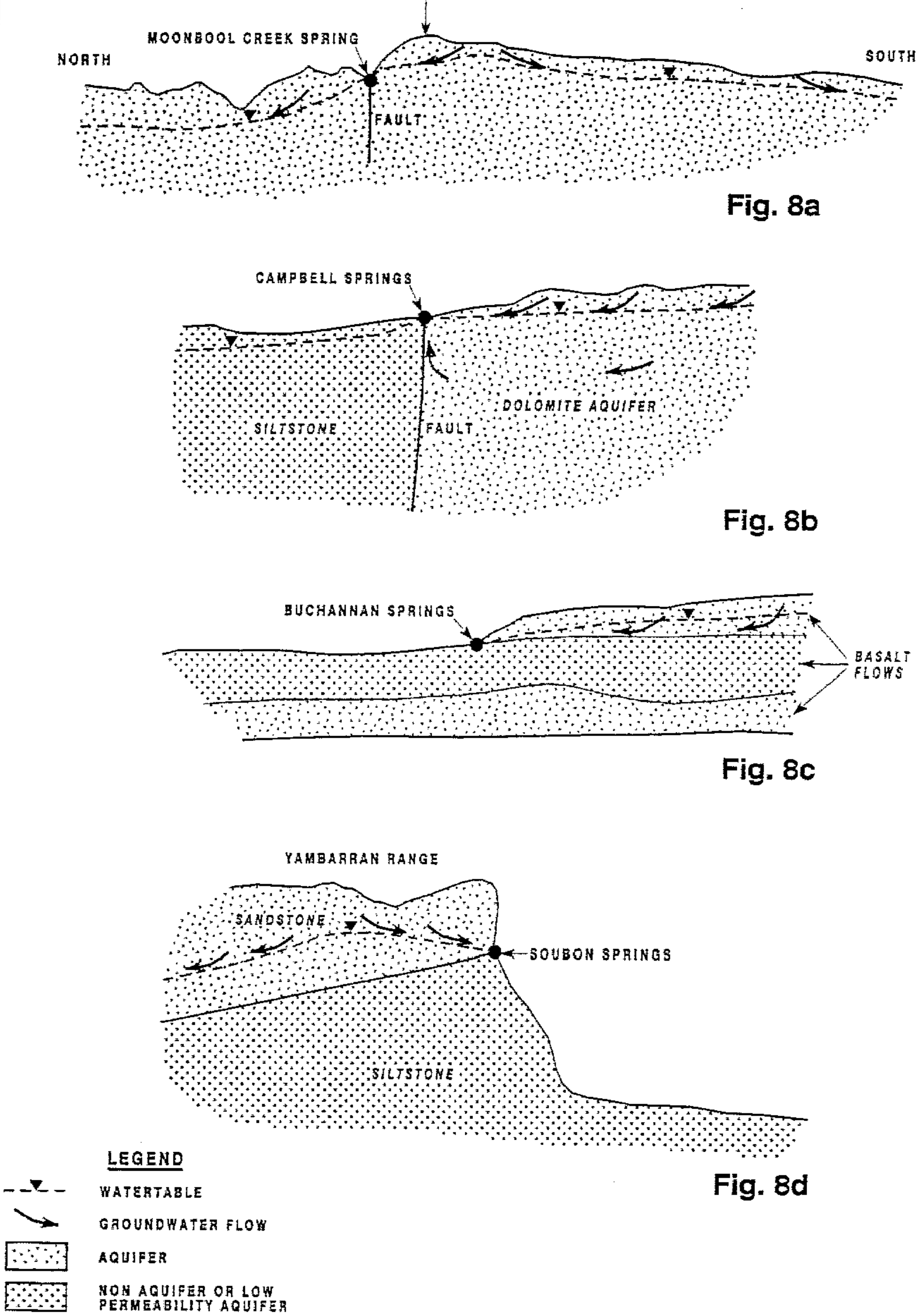
SPRINGS

Springs are natural outflow points for groundwater, occurring where the watertable is at or above the ground surface. They are widespread across the VRD, mostly taking the form of seepage into stream beds (Plate 3). Many of these are shown on Figure 5c. Some maintain waterholes but smaller ones only form small pools, losing most of their water to seepage into the downstream section of the stream bed. Although none maintain permanent river flows they are nevertheless important to both the natural environment and to the pastoral industry.

The amount and duration of flows are variable. Typically flows range from seepages up to 2 L/s, however flows of up to 15 L/s are seen in some spring fed creeks during the Dry. As the Dry season progresses the watertable drops causing a corresponding decrease in spring flows. If it falls below the ground level, flow will cease. Some springs such as Unidait Spring on Limbunya and Depot Spring on Mount Sanford are permanent but others last for only part of the Dry season. The duration of flow of these seasonal springs is often directly related to the amount of rain which fell in the previous Wet season. For example if the Wet was below average, they may not flow at all or may dry up earlier than usual. Conversely they may flow for a longer period after an above average Wet.

The location of springs is determined by either position in the landscape, aquifer location, geological structures or a combination of these factors (Figure 8). On a broad scale many of the major springs occur in the headwaters of the Victoria/Ord River drainage basins between Kirkimbi, Mount Sanford and Top Springs. The generally shallow watertables south of the drainage divide fall away rapidly to the north across the divide, forming a zone where they intersect the ground surface (Figure 8a and Plate 4).

A common geological situation in which springs form is where an aquifer is faulted against an impermeable rock such as siltstone on its downstream side. Groundwater flow is blocked and the fault provides an escape route to the surface. Campbell Springs on Limbunya is an example of this type, with a dolomite aquifer faulted against siltstone (Figure 8b). Another environment is where a near horizontal aquifer overlies an impermeable bed with the contact



TYPES OF SPRINGS IN THE VRD

Fig. 8

outcropping in a creek (Figure 8c). Such aquifers can be sandstone beds, basalt flows or the parting between two beds. Buchannan Springs on Riveren is located where the contact between two basalt flows is cut by a creek (Plate 5). Most springs occur low in the landscape but exceptions occur where the geological structure is favourable. On Bradshaw for example a series of springs issue from the heads of gullies cut into the Yambarran Range (Plate 6). They represent the overflow of a sandstone aquifer which caps the range (Figure 8d).

Although it is impossible to make recommendations on how to develop each spring, general guidelines can be made. It is important to fence them off in order to protect the source of the spring. Permanent reduction in flow could result from cattle compacting the ground or from earthworks intended to increase the flow. The spring water should be pumped or gravity fed to a collector dam, turkey nest or tank, whichever is appropriate in the situation. A small turkey nest (inner bottom diameter of 8 metres; side slope of 1 in 3 and height of 1.5 metres) with sufficient storage to supply 300 head with 6 day supply would be adequate for a uniform spring flow of 0.3 L/s. A big turkey nest (inner bottom diameter of 16 metres; side slope of 1 in 3 and height of 2.3 metres) with sufficient storage to supply 800 head with 15 day supply would be required for a uniform spring flow of 1 L/s.

TANKS AND DAMS

Man made surface water storages are not widely used in the VRD. Notable exceptions are on Bradshaw and Auvergne, two stations where groundwater supplies can be difficult to locate. Excavated tanks are the main type of storages used to harvest and store surfacewater flows (Figure 9). Smaller capacity storages such as turkey nests, galvanised iron tanks, liner tanks and concrete tanks are used as balancing storages and to gravity feed drinking troughs.

Types of tanks and dams

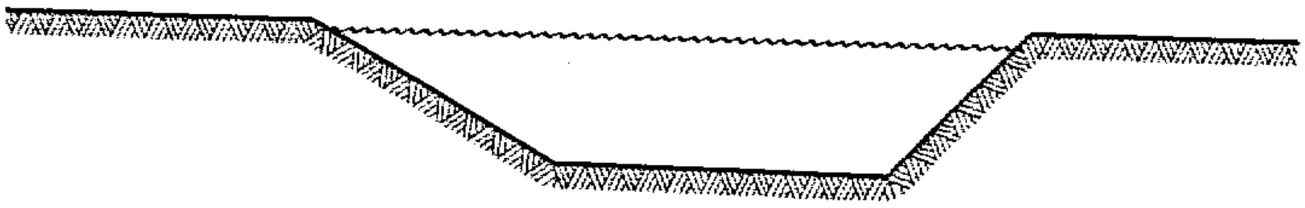
Excavated tanks consist simply of a hole in the ground and can only store water up to ground level. They are best suited to areas with very low slope such as floodplains. There are two varieties, the on-stream tank (Plate 7) and the off-stream tank. Both are of similar design but the former are located within main stream channels while the latter are located on adjacent floodplains. Excavated inlet channels are sometimes used to divert water from the main stream channel to off-stream tanks (Plate 8).

The other main types of storages are those which utilise embankments to add above ground storage capacity. On flat country excavated tanks can be enclosed by embankments to increase their storage above ground level (Plate 9). They are designed to fill through either an inlet pipe fitted with a flap gate or by pumping water into them from surrounding flooded areas during the Wet.

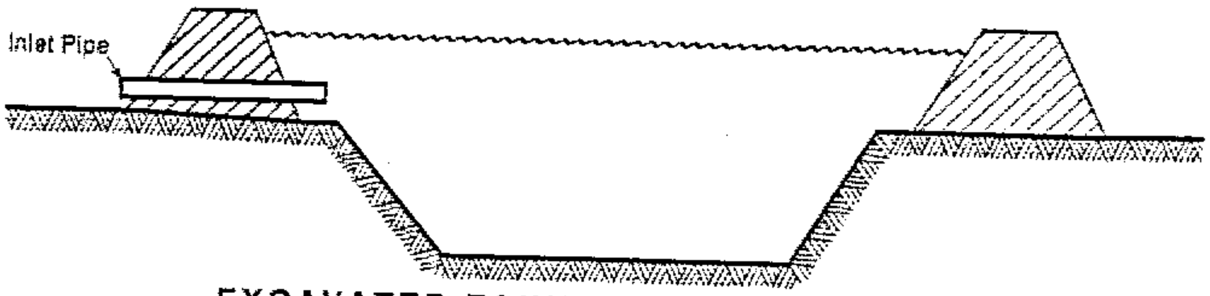
In areas with low to moderate slopes, embankments placed on three sides of an excavated tank will also add above ground storage. On moderate slopes such tanks are termed hillside storages (Plate 10) while on low slopes they are termed drainage-line tanks (Plate 11). In hilly country embankments built across gullies are termed gully dams.

Suitability

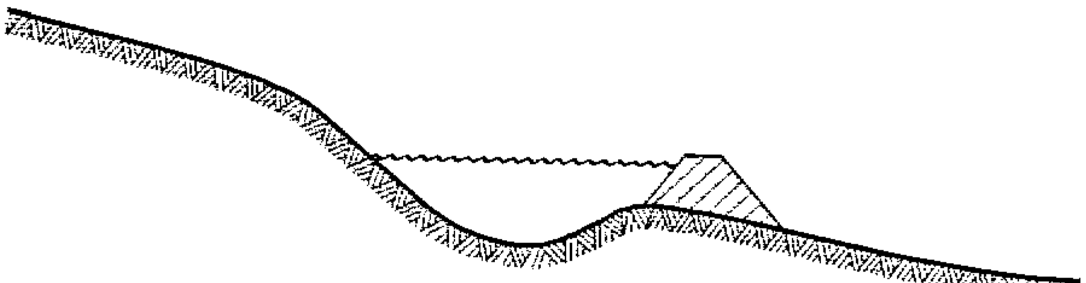
Areas in the VRD suitable for excavated tanks are restricted to the flat to gently undulating black soil country. A particular site needs to have an adequate depth of material which is easily excavated and which will hold water. For a water supply to be maintained till the end of the Dry, the depth of the tank should be more than 3.5 metres. Few locations in the region have soils which meet that requirement.



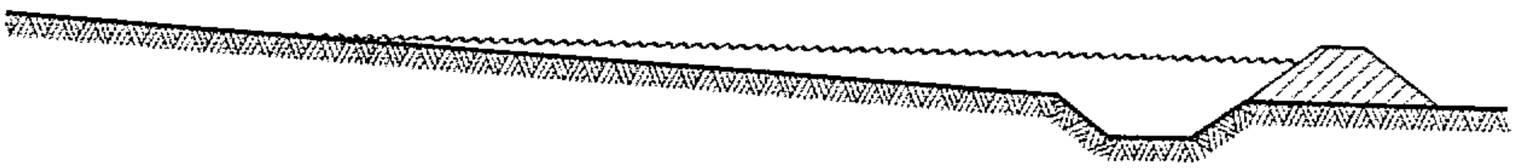
EXCAVATED TANK



EXCAVATED TANK WITH EMBANKMENTS



GULLY DAM



HILLSIDE STORAGE / DRAINAGE LINE TANK

TYPES OF DAMS AND TANKS
(Diagrammatic only)

Fig. 9

Off-stream and drainage-line excavated tanks are the recommended types because they are simple to construct and have low initial and maintenance costs. The on-stream tanks on the other hand are not recommended because they are subject to large flood flows which can lead to embankment failures. Gully dams and hillside storages involve high costs in coping with the foundation conditions and flood flows. Though there may be suitable terrain in the region, they are also not recommended. Excavated tanks with surrounding embankments are also not recommended because if they are not constructed and maintained to a high standard, their above ground storage capacity can be easily lost. On Auvergne where this type of tank has been used, they have experienced various problems including:

- Damages to inlet structures, and erosion of bund around inlet structures (Plate 12)
- Rill erosion of the bund and silting of tanks (Plate 13)
- Inlet structures are ineffective, because of malfunctioning flap gates or inadequate pipe openings.
- Inadequate spilltail channels which may lead to erosion of the bund during flood flows.

Excavated tank design

Factors which influence tank design include evaporation, rainfall, water requirement (number of cattle to be watered), slope, catchment area and soil type. Some of these are taken into account here in determining the dimensions of a tank designed to supply stock water during a "dry year" with 90% reliability (nine years out of ten). A full "dry year's" supply is taken to be the twenty months from April soon after an average wet year to December in the next year when rain starts again. The size of the design tanks considered, varies from 60 x 60 x 2.0 to 100 x 80 x 4.0 metres. The water requirement is calculated from the number of head and from an assumed average consumption of 50 litres per head per day.

The annual lake evaporation for the region is assumed to be 2.4 metres/year or 4.4 metres for the 20 month period. The depth of any storage should therefore be at least 6 metres to supply water to a several hundred head. In reality however the maximum depth of water retaining soil is normally less than 3 metres. In some areas rippable shale is found below the soil and the water retaining depth can be increased to 4.5 metres or more. Even a 12 month supply would require a minimum depth of 3 metres and it would be hard to maintain 90% reliability, depending on the number of stock.

The design dimensions also depend on the annual rainfall. In the northern part of the region where rainfall is twice the amount of that in the south, a water supply for 12 months would mean the depth should be more than 3 metres to supply a typical number of stock with 90% reliability. In the central VRD, a 9 month supply would mean the depth should be 4 metres or more. If the depth is between 2 and 3 metres, the supply is restricted to less than 6 months still maintaining a reliability of 90%. In the southern part of the region, for the same range of depths the reliability reduces to 80%, and the supply is restricted to four months or less.

Tanks of moderate size (eg.60 x 60 x 2.5 to 100 x 80 x 3.5 metres) can supply 200 to 400 head with 80 to 90% reliability for periods between 4 and 12 months, depending on the depth of tank and its location within the region. Large deep tanks can supply more than 500 head over a 12 month period, but it may not be feasible to construct them due to insufficient depth of suitable soil. The storage capacity of the design Off-Stream and Drainage Line tanks is less than 1%, and 2% of the average annual rainfall respectively. The surface runoff ranges up to 15 % of the average annual rainfall for large catchments but small catchments of a uniform nature may yield more than 25%.

The catchment area of a drainage-line tank is small and for design purposes an area of 2 km^2 or less is adequate. The off-stream tank requires a minimum catchment area between 4 and 8 km^2. Streams with catchment area more than 30 km^2 would have the potential of providing water to more than one excavated tank en route.

Site investigations and construction

Usually an initial site is chosen based on where the water is needed and where sufficient water will be able to be captured. Following that, detailed site investigations are recommended before excavation begins. These will determine if there is sufficient depth of material which can be economically excavated and whether or not significant leakage will occur. Simple soil tests which can give this information are detailed in Technical report 12/1998D (*3).

SUSTAINABILITY OF WATER SUPPLIES

Water supplies are obviously directly dependant on rainfall, so a knowledge of past climatic variations is essential in determining if present levels of water usage can be maintained. The VRD covers a vast area and spans the humid and semi-arid climatic zones. As a consequence it experiences considerable variation in rainfall, both across the area and with time. In a particular season some regions can receive above average rainfall while others can be below their respective averages. Figure 10 illustrates this by comparing long term annual rainfall from two stations, Wave Hill in the southern VRD and Rosewood in the north.

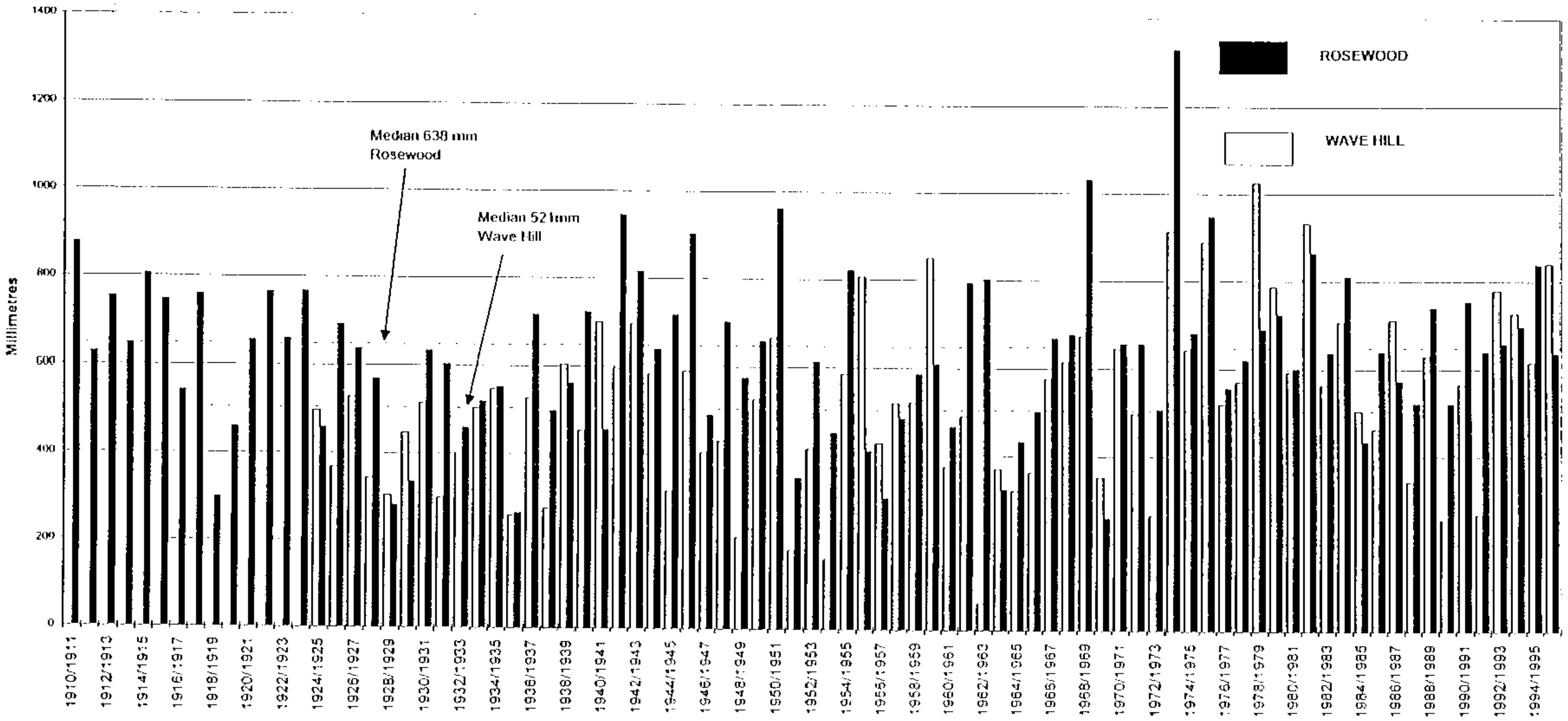
Longer term cycles of drought and wet periods are also apparent. Major droughts have occurred in the past, for example during the late 1920's and 1930's. On a broad scale, the pattern of wet and dry periods is similar across the region but in detail one area can be in drought while another is not. It is important to note that the period from the early 1970's to the present has been relatively wet compared to the preceding record.

In view of the variability of rainfall, several points are now discussed: How do droughts specifically affect different water sources? Can present levels of water usage be sustained during droughts? and What measures can be taken to lessen the effects of drought?

EFFECTS OF DROUGHTS ON WATER SOURCES

Groundwater levels respond in varying degrees to the preceding seasons rainfall or lack of it. Most aquifers in the VRD are of the fractured rock type with limited storage in comparison with the more extensive type of aquifer found elsewhere. Observations made at Rosewood and Lajamanu suggest that recharge and thus a rise in water level will only occur if rainfall is above the average. Spring flows and water levels in bores and wells are both directly affected by water table fluctuations. If levels drop sufficiently, bores may have insufficient water above the pump inlet to maintain the normal pumping rate. In the extreme case of shallow bores and wells, they can potentially dry up completely if the water table falls below the slots in the casing or the base of the well. The effect on springs would be to reduce the duration and amount of flow. Similarly spring fed waterholes would not last for as long as during normal seasons.

The effect of drought on dams and non-spring fed waterholes is obviously that they may not be replenished as often as normal and in extreme cases will not be replenished at all for several seasons.



Rainfall at Rosewood and Wave Hill 1910 - 1996

Note years measured from June to May and data from nearby stations were used where there were gaps in the record

Fig.10

PRESENT WATER USAGE

Stock bores are spaced widely and are pumped at comparatively low rates, so the present usage would have to be rated as fairly low. There is no evidence of widespread groundwater level decline over time, related to the increasing number of bores, eg. progressive lowering of pumps. During droughts however watertables would be expected to lower sufficiently to cause local failures of bores, wells and springs. Those most susceptible would be shallow bores, bores tapping marginal aquifers (ie. those which cause a high drawdown for a given pumping rate) and springs which normally have low flows and flows of short duration. Drought effects would also be more severe in the lower rainfall southern regions. Anecdotal evidence from landholders indicates that during past droughts only a few wells and bores. particularly shallow ones have gone dry. Some deeper bores have required pumps to be lowered to maintain a supply but most have been unaffected. A more common observation is that some spring flows have been reduced and spring fed waterholes depleted earlier than normal.

The best dams generally can only hold a maximum of nine months supply and most have considerably less usable storage. Low rainfall would therefore render most dams ineffective. The same scenario applies to non-spring fed waterholes. Surfacewater supplies in general are therefore more sensitive to drought than groundwater because the latter has a large storage to buffer short term variations in recharge.

REDUCING THE EFFECTS OF DROUGHT

For existing bores two options may be available to maintain a supply if water levels drop too far. If there is additional depth between the pump inlet and the top of the slots in the casing, the pump can be lowered to stop the bore "forking" (drawing the water level down to the pump inlet and causing it to take in air). If this is not an option, then reducing the pumping rate will lessen the drawdown and may avoid forking.

In the case of a new bore, drilling a bit deeper than is necessary can often result in additional water intersections. This enables a greater length of slotted casing to be placed in the aquifer, reducing the drawdown for a particular pumping rate. This will add to the cost of the bore but in the long term it will be worthwhile especially if it saves the pump having to be lowered. Even if no extra water bearing zones are found the maximum number of slots should be cut without compromising the strength of the casing. Accurate placement of the slotted interval is also essential in reducing drawdown when pumping.

The best way to increase the reliability of a dam is to increase it's depth. Increasing the area of a dam will only add more longer term storage if the depth is greater than the depth of water which will be lost to evaporation. Unfortunately this is only possible in a very limited number of sites in the VRD due a general lack of suitable deep soils. A way to overcome this depth limitation is to build embankment dams. Although these have not been recommended here because of potential damage by high flood velocities, they do provide a way to increase the storage depth beyond that possible with a ground level excavated tank. A large embankment dam may also have the potential to provide water for limited irrigation, thus extending the stock feed supply at least in the early part of a drought.

A problem that arises during droughts is that although there may be both adequate water and feed, the two may be located in different places. As drought progresses and areas are eaten out, cattle progressively move outwards from the watering points, until a point is reached where the distance that they have to travel between feed and water becomes too great.

This is normally overcome by either providing more bores or dams or by extending the range of the existing sources via pipelines. The latter option would generally be preferred because of costs. Even in normal seasons multiple watering points originating from a single water source have the potential to reduce the grazing pressure on the soil and vegetation. Studies by the CSIRO (*4) have indicated that artificial water sources have had a strong impact on the biodiversity of the flora and fauna. Increasing the number of watering points and at the same time increasing the number of cattle would obviously worsen the situation. On the other hand spreading the same number of cattle over a larger area would likely be beneficial in regards to biodiversity, soil conservation and also the condition of the cattle.

WATER RESOURCE DATA, LOCATION AND AVAILABILITY

Borehole Information

Copies of the bore completion reports submitted by drillers are held at the Natural Resources Division in Darwin. The information is in both digital form and as paper copies. It is available on request and charges only apply for copying large amounts of data.

Selected borehole information for the VRD study area is included on a CD-ROM titled "Water Resources of the Victoria River District". This is available on request from the Natural Resources Division.

Water resource maps

Individual maps are available for twenty one properties in the western VRD. These are published at 1:100.000 scale and show regional variations in groundwater conditions and suitability for excavated tanks, together with the best options for developing a stock water supply in a particular area. The eastern VRD is largely covered by three 1:250,000 scale groundwater maps. The map accompanying this report covers the whole of the VRD. Hard copies of all these maps can be obtained from the Natural Resources Division in Darwin. The maps are stored in digital form as MicroStation "Design Files" and that data is also available to interested parties.

Water resource and Land Unit information covering Mount Sanford station have been combined in digital map form on a CD ROM. The data can be viewed and queried using the program ArcExplorer which is also included on the CD. This was done as a trial to test the usefulness of this form of information. Similar exercises may be conducted for other properties in the future if there is demand for it. The Mount Sanford CD is available on request from the Natural Resources Division.

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GLOSSARY OF TERMS

Airlift Yield: The rate at which water is extracted from a bore with compressed air as drilling takes place.

Alluvial: Formed by the action of rivers

Aquifer: A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to bores and springs.

Floodout: A stream which issues from hilly country and fans out into numerous channels onto adjacent flatter ground

Groundwater: Subsurface water contained in the saturated zone.

Karstic: Related to solution features in limestone or dolomite.

Lake evaporation: The amount of water lost by evaporation from a free standing body of water, commonly measured in millimetres.

Laterite: A residual material formed through the prolonged weathering of rocks, probably under warm wet conditions.

Median: The value of the middle item in a set of data arranged in rank order.

Pan evaporation: A meteorological term for evaporation as measured with a Class A. Australian evaporation pan, commonly measured in millimetres.

Recharge: Addition of surface water to the saturated zone to become groundwater.

Spill tail channel: A channel built downstream of the spillway to direct excess water back into the creek.

Standing water level: The level below ground surface, to which groundwater rises in a bore.

Topography: The shape and height of the landsurface

Plate 1 Turkey Nest Dam and bore, Bunda. Note they are fenced to keep the stock out.

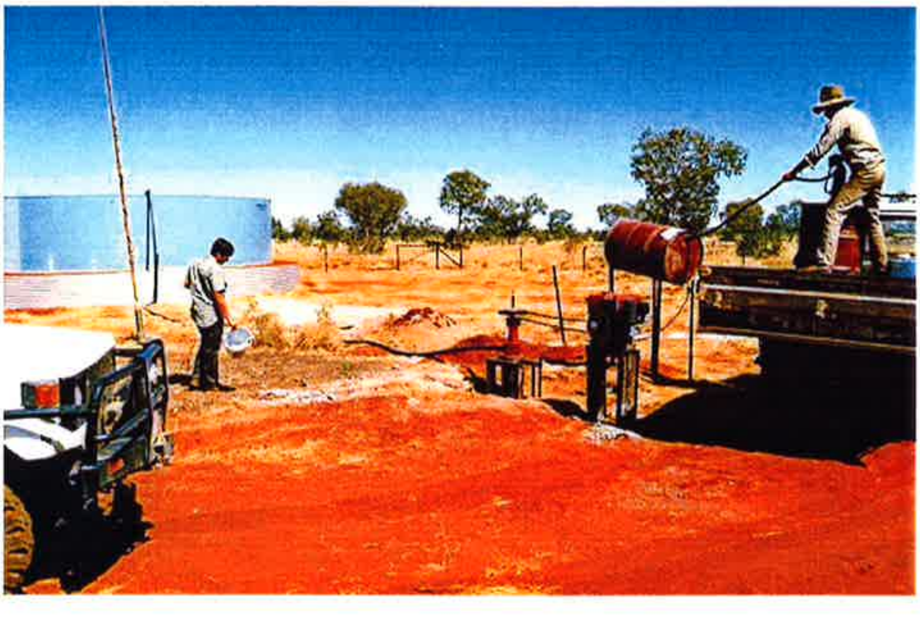

Plate 2 Andersons Bore, Cattle Creek, a typical stock bore.

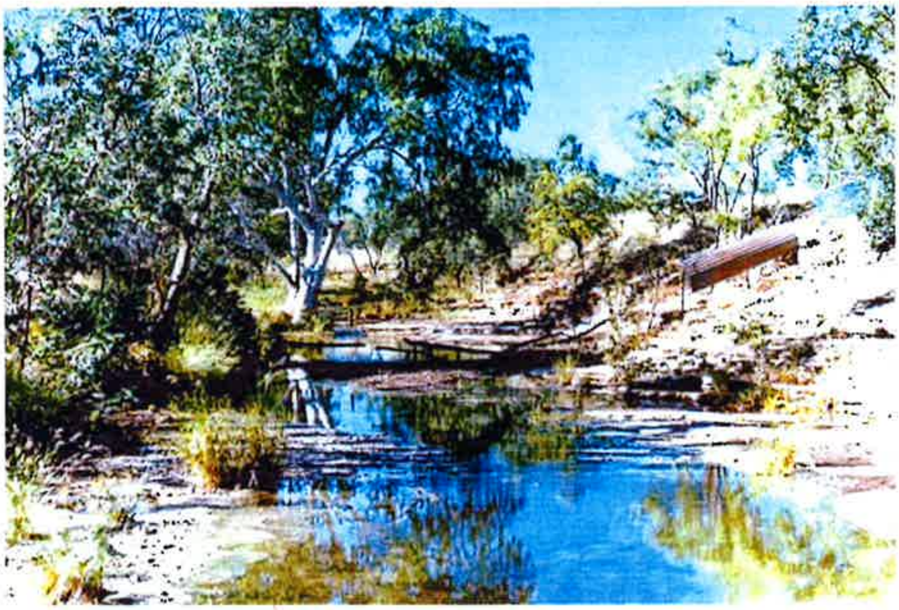

Plate 3 Kelly Bore Spring, Mistake Creek, a fault controlled spring in limestone.

Plate 4 Moonbool Spring, Kirkimbi, the drainage divide between inland and seaward flowing streams is located near the edge of the grassy plain in the background.

Plate 5 Buchannan Springs, Riveren, the water seeps out between two horizontal basalt flows.

Plate 6 Camballin Springs, Bradshaw, water seeps out at the base of the sandstone cliff.

Plate 7 Nesmit Tank, Auvergne, an on-stream tank, located within a prominant drainage line, note the turkey nest on the left.

Plate 8 Horseshoe Dam, Auvergne, an off-stream excavated tank with a short inlet channel.

Plate 9 Cedar Lagoon Tank, Auvergne, an off-stream excavated tank with above ground storage, note the turkey nest on the right edge of the tank, used to gravity feed water to the troughs.

Plate 10 Burkes Dam, Bradshaw, a hillside storage.

Plate 11 Police Hole Tank, Auvergne, a drainage line tank.

Plate 12 Four Mile Dam, Auvergne, the embankment has been damaged around the inlet pipe by flood waters.

Plate 13 Rill erosion of the embankment of No.2 Dam, Auvergne.