POWER AND WATER AUTHORITY
WATER RESOURCES DIVISION

WATER RESOURCES SURVEY OF THE
WESTERN VICTORIA RIVER DISTRICT

RIVEREN STATION

REPORT 20/1996D
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Darwin
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WATER RESOURCES SURVEY OF RIVEREN STATION
NORTHERN TERRITORY

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Water Resources of Riveren
LIST OF ABBREVIATIONS

- km
- L/s
- m
- m³
- mg/L
- ML
- mm
- µS/cm
- pH
- TDS

- kilometre
- litres per second
- metre
- cubic metre
- milligrams per litre
- megalitre (one million litres)
- millimetre
- microsiemens per centimetre
- acidity and alkalinity index
- total dissolved solids

LIST OF CONVERSIONS

1 mm (millimetre) = .04 inches (4 points)
1 m (metre) = 3.3 feet
1 km (kilometre) = 0.6 miles
1 L (litre) = 0.22 gallons
1 ML (megalitre) = 220,000 gallons
1 L/s (litre per second) = 800 gallons per hour

Water Resources of Riveren
SUMMARY
The accompanying Water Resources Development maps can be used as a guide to determine the type of water supply most appropriate to specific areas of the station. Small to moderate supplies of groundwater are generally available in most areas but considerable effort and expense may be involved in locating it. In situations where surface water flows and soil types are suitable, excavated tanks away from clearly defined drainages, and sited to harvest sheet flow may be an alternative option to bores. Few areas are likely to have sufficient depth of clay soil to enable the construction of tanks with enough storage to last most of the dry season. Sites could be found however for shallower tanks which could supply water at least for the early part of the Dry.

1. INTRODUCTION
This project was started by the Victoria River District Conservation Association (VRDCA). Its aim is to provide station managers with up to date information on water resources, so that they can make more informed decisions about water and land management. It is funded by the Northern Territory Government and the National Landcare Program with a contribution by the VRDCA. A total of 20 properties will be studied between July 1993 and June 1998.

Riveren station covers an area of 1850 km² and is located some 280 kilometres southeast from Kununurra, the closest major town. Road access is via the Buchanan Highway which remains open for most of the year (Figure 1). During the wet season many station tracks may be impassable.

The availability of stock water is the major influence on stock management. Nearly all of the annual rainfall, which averages approximately 527 mm, occurs in the short hot monsoonal wet season between December and March (Table 1). Little rainfall is experienced during the remainder of the year. Recharge to groundwater aquifers occurs at this time. Evaporation rates of water bodies such as dams or waterholes are between 4.5 and 8.6 millimetres per day (average about 6.8 mm per day or 2.5 metres per year). This ensures that water levels in creeks, dams and tanks decline rapidly. Air temperatures are high throughout the year. The average monthly maxima range from about 26.5 degrees in June to 38.0 degrees in December. The corresponding average monthly minima are 9.7 and 22.9 degrees. These temperatures were recorded at the neighbouring Inverway Station.

Current stock management is based on water availability. At present the station carries about 9,600 head of cattle. Bores supply approximately 50% of the water need, the remainder coming from springs and waterholes. Twenty one bores are used, normally in conjunction with turkey nests which act as temporary storages. During the Wet and the early Dry, most of the available surface water that is accessible is used, but as the Dry progresses, these sources become depleted and more reliance is placed on groundwater except for few waterholes in the Victoria River that last throughout the year. There are two excavated tanks but only one is being used and that only caters for a small number of stock for a few months.

The station can be classed into two broad landform types, the laterite plateau and the dissected plateau (Figure 2). The laterite plateau is an ancient landscape with subdued topography. Laterite is an iron rich rock resulting from soil forming process under a wetter climate than today’s. Soluble minerals in the bedrock were dissolved out but the insoluble iron minerals remained and accumulated as a crust of laterite, eventually forming a plateau. It remains intact north of Fault Bore and on the western boundary with...
RIVEREN STATION LOCATION MAP

Figure 1
**TABLE 1**

**CLIMATIC AVERAGES - RIVEREN STATION**

<table>
<thead>
<tr>
<th></th>
<th>RAINFALL (mm)</th>
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<th>DAILY MIN. TEMP (°C)</th>
<th>DAILY MAX. TEMP (°C)</th>
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<td>34.0</td>
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<tr>
<td>APRIL</td>
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<td>16.7</td>
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<td>JULY</td>
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<td>OCTOBER</td>
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<td>2</td>
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<td>36.2</td>
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<td>5</td>
<td>22.9</td>
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<tr>
<td>TOTAL</td>
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<td>36</td>
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</tr>
</tbody>
</table>

Note: Temperatures are from Inverway Station

*Water Resources of Riveren*
SCALE 1 : 500000

LANDFORM MAP OF RIVEREN STATION

Figure 2
Inverway. A good profile through the laterite can be seen on the jump up just north of Fault Bore. A small black soil plain occurs on the laterite plateau adjacent to Burrata Wurta Creek and it represents its alluvial deposits.

Over the rest of the station the Victoria River and its tributaries have eroded back into the plateau, forming the gently undulating country of the dissected plateau. Remnants of the plateau are preserved there as isolated flat topped hills, such as Mt Farquharson. It is an area of active erosion, so its soils are relatively thin. The divide between streams flowing to the sea in the Victoria River catchment and those flowing inland in the Sturt Creek and Hooker Creek catchments runs across the southwestern corner of the station.

2. WATER SUPPLY DEVELOPMENT

An attempt has been made to classify the station according to the type of water resource developments considered most appropriate for particular areas. The results are shown on the accompanying Water Resources Development Map of Riveren. The map was made by combining information on existing features (waterholes, dams, bores etc.) with information on groundwater occurrence, topography and soil types. Local conditions, such as soil types can vary considerably, so the maps should not be taken as a definitive guide to cover every situation. Rather they are broad scale maps which are intended to give an overall picture of possible development options. Detailed on-ground investigations are recommended when considering specific developments.

For an explanation of the colours on the main map refer to the legends entitled "Water Resources Development Options".

Four categories of "preferred options" have been mapped:

- areas which are unsuitable for surface water storages or bores (option 1).
- areas in which surface water is the best option (option 2).
- areas in which groundwater is the best option (option 3).
- areas in which surface water and groundwater may both be viable options (option 4).

Some of the main features of the maps are:

- groundwater is available in most areas except in the northern area of the station.
- areas suitable for the construction of excavated tanks are restricted to alluvial soils adjacent to streams and black soils. Most of the areas mapped as suitable for surface water development could be considered only marginally suitable because they may have insufficient depth of water retaining soil to construct tanks.

3. GROUNDWATER

Groundwater conditions across the station have been assessed using geological information, satellite images, aerial photos and information from existing boreholes. The results are presented as the Groundwater Resources Map, a small side maps on the accompanying map of Riveren station.

Technical information on water bores is shown in Appendix 1. Further details on individual bores are held on the Water Resources Division's files and are available on request. Chemical analyses of groundwaters and recommended limits for common uses are listed in Appendix 2 and
3, while the results of the pump testing program are presented in Appendix 4. Groundwater is stored in and moves through minute spaces in rocks caused by fractures (cracks), the spaces between sand grains or spaces where minerals have dissolved away. If economically viable quantities of water can be extracted, the water bearing horizon is termed an aquifer. The zones of groundwater yield shown on the maps are meant to give an indication of the most likely yield which could be expected. Natural variations in the properties of rocks means that variation also occurs in groundwater yields. For example in a zone mapped as 0.5 to 5.0 L/s a certain percentage of bores may obtain higher yields and some may be lower but most will fall within the range. At a specific site, yield is often highly dependent on the number of water bearing fractures intersected. There are generally too few existing bores to determine the likely yields with statistical certainty. Rather they are based on a combination of geological knowledge and known yields.

A paddock holding 1000 head of cattle (each consuming 50 litres per day) requires a bore capable of pumping between 0.5 and 1 L/s continuously. Bores yielding less than 0.5 L/s are generally regarded as being uneconomic.

Stock water is presently obtained from twenty one bores. Water drilling has been only moderately successful with twenty five of the fifty six bores drilled on the station being abandoned due to insufficient yield. Five bores are not used due to unsuitable water quality. Standing water levels are generally shallow, especially in the headwaters of the Victoria River catchment. Revolver Creek bore (RN20171) is artesian (its standing water level is above ground level) and numerous springs occur in the headwaters.

Prospects for successful bores can be improved by siting bores along fractures or faults identified on aerial photographs or satellite images. A major east-west fault has been traced from the Northern Territory Geological Survey's "Limburya Aeromagnetic Map". Higher than average yields could be expected along this fault. Three bores, Fault bore (RN20360), Salt Creek bore (RN9971) and Neave Creek bore (RN20169) located on or near this feature obtain yields of 8.2, 3.0 and 3.0 L/s respectively. A magnetometer survey could be used for its precise location on the ground, however the fractured zone probably extends over a width of several hundred metres and the present map should be adequate for drill site location.

Excessive concentrations of fluoride and associated high pH values limits the usefulness of some groundwaters on Riveren. High fluoride is mainly restricted to waters from basalt aquifers, at depths ranging from 12 to 90 metres. Fluoride may be a primary constituent of the volcanic rocks, possibly more concentrated in certain horizons such as volcanic ash deposits or it may have originated from mineralised veins which have cut through the basalt. Veins of barytes, a mineral commonly associated with fluorite (calcium fluoride) occur in basalt on Kirkimbie but no occurrences of fluorite itself have been reported to date.

Values of fluoride above the recommended limit for stock occur in several bores in the vicinity of the homestead and in the bores RN23183 and RN20171 to the northwest. In addition to those, groundwaters from some fourteen other bores are unsuitable for human consumption due to excess fluoride. Note that the recommended limit for human consumption (Appendix 3) ranges from 0.5 to 1.7 mg/L. The reason that a range rather than a single value is
given is because the effects of fluoride can vary with temperature. In a hot area such as the VRD the lower limit of 0.5 mg/L should be observed. Fluoride can be removed from household drinking water with an ion exchange unit or by batch-treating tankfuls of water with bicarbonate of soda (to bring the pH down to 7-8) and then adding alum to precipitate the aluminium hydroxide and the fluoride. Treatment for stock water is likely to be uneconomic.

Saline water unsuitable for stock was encountered in the bore RN20080 in the southwestern corner of the property. Water of similar poor quality also occurs immediately to the west on Inverway. It is probably associated with the black soil plain on which both bores are located. Any further bores in that area should be sited on tree covered country adjacent to the plain. Elsewhere on the station there are five bores which struck water which is too salty for human consumption.

The two yield zones on the groundwater map are now described:

3.1 Areas with yields 0 to 0.5L/sec

This zone covers most of the northern section of the station, north of Fault bore. The low yields obtained result from the underlying siltstone, dolomite, shale and sandstone being only poorly fractured. No successful bores have been drilled in that area, despite some being up to 120 metres deep. Chances of success may be improved slightly by siting bores on faults or fractures identified on aerial photographs. A laterite capping over much of the area tends to obscure such features however.

3.2 Areas with yields 0.5 to 5L/sec

Three major rock types, basalt, granite and sandstone form aquifers in this zone. Basalt underlies the major part of the station and most of the production bores tap it. Only half of all the bores drilled into basalt obtained sufficient water for a stock supply, suggesting that the aquifers are only local in their extent. Yields can range up to 5 L/s but are usually less than 2 L/s (Figure 3). Most supplies occur between 10 and 20 metres, although water has been obtained from as deep as 160 metres (RN26799). Five bores struck water between 80 and 100 metres. Aquifers can be formed in basalt in four geological environments, including:

- weathered rock down to 30 metres depth. Fractures in the weathered rock tend to be more open and capable of transmitting more water than those in fresh rock. The layer of weathered rock however is not a continuous sheet across the area as it has been partially stripped away by stream erosion. In other areas it lies above the watertable and so no shallow aquifer is present.
- contacts between individual basalt flows. Basalt is a volcanic rock made up of many solidified lava flows. The tops of the flows tend to be more fractured than their centres because the rock cooled quickly when it was exposed to the air. Buchanan Springs owes its presence to such a permeable zone. Two distinctive basalt flows can be seen in the creek bed and the spring issues from the contact between them.
Figure 3 Depth water struck / Yield, basalt aquifer
basalt flows which are more fractured than usual. The bore RN26799 struck water in a gray brown basalt at a depth of 150 metres. The overlying basalt was dark gray and contained no water. The five bores which struck water between 80 and 100 metres probably also intersected a permeable basalt flow.

along faults. Rocks adjacent to faults tend to be more fractured than those which are remote from faults. Some of the station bores were sited on faults identified on aerial photographs.

Most of the basalt aquifers on Riveren are of the shallow weathered rock type, although many are probably combinations of two or more of the aquifer types.

Another rock type included in the 0.5 to 5 L/s zone is sandstone on the north eastern corner of the station. Aquifers occur in two geological formations known as the Seale Sandstone and the Hughie Sandstone. Two bores, Burtawurta bore (RN20412) and RN26731, both successful have been drilled in this area. Yields of 2.3 and 4.5 L/s respectively were obtained from a depth of about 30 metres. Burtawurta bore may be more typical of yields which could be expected from these formations as the other bore is located in the vicinity of a major fault. It is likely that aquifers are only patchily developed in granite.

4. SURFACEWATER

Surface water flow in the creeks and on the floodplains is largely confined to the wet season. Some creek flows and replenishment of waterholes during the Dry are due to spring flows. An effective annual evaporation rate of about 2.5 metres is responsible for the subsequent rapid loss of stored water from tanks and waterholes. During the average Wet, flow of the Victoria River, and its tributaries Revolver Creek, Horse Creek and minor streams are sometimes accompanied by sheet flow over the adjacent floodplains. After the Wet, all drainages deplete to form unconnected waterholes, the majority of which are dry by about July. Surface water studies have been directed at designing structures to conserve enough of the wet season flow to provide reliable stock supplies for the duration of the Dry. An example of typical storage requirements would be 4.7 megalitres (million litres) for a paddock holding 350 head (50 litres/head/day) after allowance is made for evaporation losses. That would ensure a 9 month daily stockwater supply from April till December.

For its stock water supplies from surface water the station is dependent on waterholes, springs, and an excavated tank. About 50% of the stock water demand on Riveren is supplied from natural and artificial surface water sources.

The region has been divided into five zones showing the suitability for surface water development for stock watering. They are based on soil type, geology, topography and runoff characteristics. The results are
presented as the Surface Water Resources Map, one of the two small side maps accompanying the Water Resources Development Map.

4.1 Surface Water Storage Types

Three types of excavated tanks are suitable for the flat to gently sloping blacksoil plains, onstream tanks, offstream tanks, and drainage-line tanks (Figure 4). An onstream tank is one dug in a well defined stream channel. Offstream tanks are constructed away from the main channel but are connected to it by an excavated inlet channel. The third type, the drainage-line tank is the preferred option and is one which is sited along a broad poorly defined watercourse.

The onstream excavated tank requires a high standard of design and construction and is prone to erosion or silting because of its location in a fast flowing main stream channel. The offstream design (Figure 5) reduces these problems by using a man-made channel to divert water from the stream to the tank. This is an improvement on the onstream design, but has excessive excavation costs because to take advantage of short lived stream flows, the tank level must be below that of the natural stream bed.

The drainage-line tank (Figure 6) is an excavated tank constructed in flat to moderately sloping areas where there are no clearly defined incised creek systems. The tank itself is of the same design as the offstream one, but without an inlet channel. Sheet flow on the plains, with its low silt load, may be harvested using catch drains or wing walls.

Water Resources of Riveren

Another type of dam, the gully dam is suited to gently undulating to hilly country and consists of an embankment built across a drainage line. It should be noted that structural failures are high amongst gully dams, as they require a high standard of design, construction and management. Construction of these dams in much of the low hilly country on Riveren may not be economically feasible due to the thin permeable soils and underlain by basalt bedrock. Areas where soils are clayey may be locally suitable for gully dams. The minimum average depth of the dam should be 4.5 metres in order to compensate for the high evaporation, and to maintain a high reliability. All excess runoff has to be taken through a by-wash or spill.

Constructing a gully dam at an appropriate location in the region would involve high costs in coping with the foundation condition and flood flows. It is recommended to consult a Civil Engineer before planning to construct these dams on rock foundation. Embankments more than 3 metres high need licensing from the Water Resources Division.

Details of the station’s key surface water storages and an assessment of their capabilities are given in Appendix 5. The existing man made reservoirs are shallow excavated tanks with bunds made from the excavated material and open on the upstream side. From the top of the bund these tanks are about 2 to 3 metres deep, but with a maximum excavated depth of less than 2 metres. The Home Dam which is an offstream excavated tank experience the following problems:

- rill erosion of the bund and silting of the tanks.
- inadequate spilltail channels do not direct water away from the bund.
SECTION CD

SECTION AB

PLAN
NOT TO SCALE

TYPICAL OFF STREAM EXCAVATED TANK

Fig. 5
TYPICAL DRAINAGE-LINE EXCAVATED TANK

Fig 6
walls prompting breaching and erosion of the walls.
- silting of catch drains

Regular maintenance is required before the next Wet to correct damage due to these problems. The current design does not give sufficient storage capacity for cattle requirements, due mainly to high evaporation losses. The depth of excavated tanks should be 3.5 to 4.5 metres, depending on subsoil types. As the depth increases beyond 3.5 metres, the tank’s reliability increases.

4.2 Selection of Sites for Excavated Tanks

The selection of a site for an excavated tank is determined by the availability of runoff and the water holding capacity of the ground. A drainage-line tank is best located on flat or gently sloping ground. Excavation will be minimised where the tank site has some slope, say about 1%, to allow bunds constructed from excavated material to add to the storage volume of the tank. On areas mapped as "gently undulating country with cracking clay soils" on the Surface Water Resources Map, clays soils may extend in places to depths of up to 3 metres and will be suitable for excavated tanks. However it should be noted that over most of that area it is likely that there will be insufficient depth of suitable soil for tank construction. The two most favourable areas include the black soil plains adjacent to Burtawurta Creek and on the stations southwestern boundary with Inverway. Areas mapped as "narrow alluvial plains" may also be suitable, however places with sandier soils should be avoided. Drainage-line tanks may be feasible in areas immediately adjacent to the low hilly country if clayey soils with sufficient depth are present. Areas suitable for consideration are also summarised on the Water Resources Development Map. Following selection of a general area, more detailed investigation is required (Appendix 6) and may require the input of a geotechnical consultant.

For drainage-line storages a minimum catchment area of 1.5 km² is required. Other types of excavated tanks require a minimum catchment area of 3 to 4 km². Cracking clay soils are suitable for holding water. Remedial work such as installing a clay liner, or reselection of the site will be necessary where dispersive or sandy soils, or high permeability zones are encountered.

4.3 Design and Construction of Excavated Tanks

Design dimensions for an excavated tank are determined by the number of stock to be watered. This is also dependent on the carrying capacity of the paddock, typically varying between 150 and 2500 head. At a consumption of 50 litres per head per day the corresponding water requirement is between 3.7 and 16.4 megalitres per year. The amount of runoff that can be captured by a tank increases with catchment area.

A drainage-line tank of the design shown in Figure 6 and with a catchment area of 2 km², would supply 150 head of stock, through out the year on a daily basis with 90% reliability (ie. for 9 years out of 10). This same tank with daily supply during the Dry only (9 months) could cater for 400 head with 90% reliability. Tank sizes of 100 x 100 x 4.5 or 100 x 80 x 4.0 metres could supply stock water on a daily basis for 200 to 300 head with a reliability of 90% over a year.

An offstream tank of the design shown in Figure 5 and with a catchment area of 4 km² should supply 200 head of cattle, with
80% reliability. If shallower than 3.5 metres or if the catchment area is less than 8 km², it would be unable to cater for a continuous water demand. Due to the region's relatively low rainfall, a reliability as low as 80% might be considered satisfactory. An Offstream tank of size 100 x 100 x 4.5m could cater for 250 to 300 head of stock on a daily basis over a year with 90% reliability. This tank could cater for about 400 to 500 if the demand is restricted to the first nine months of the dry.

The design of excavated tanks is covered in more detail in the internal Water Resources Division Report No 16/1996D, entitled "Surface Water Storage Potential - Riveren Station". The proposed design is relatively simple. Excavated spoil can be dumped to waste or used to build a bund on three sides of the tank. A bund and wing walls will increase the storage capacity of an drainage-line tank where there is a moderate slope on the natural ground surface. Excavated volumes are large for the proposed design dimensions (approximately 20,000 m³) so construction costs will be high. Cost will also be influenced by ground conditions. Tank construction is described in more detail in Appendix 7.

4.4 Waterholes and Springs

Natural waterholes are present during the Dry, in depressions in streambeds. Some of the waterholes are spring fed and never dry even though they are shallow. There are waterholes in major creeks such as Gum, Horse and Revolver Creeks. The Victoria River also has few waterholes, some of which are very long and deep and generally last for most of the Dry. The available capacity of some waterholes may be increased by excavation of the base

*Water Resources of Riveren*

Springs usually occur on hill slopes and in stream beds. The four main springs in Riveren are Buchanan, Rocker, Salt Trough, and Dinner camp. Springs are also found in Revolver Creek and Victoria River. The springs in the station are not protected, and cattle have direct access to them. A spring with a flow of more than 2 litres per second at the end of Dry, should be able to supply a turkey nest designed to store three days supply of stock water for 500 head of cattle. Piping water from springs to areas where groundwater or surface water are not available may be an option in some situations.

4.5 Piping of Surface Water

On some stations surface water has been piped from borrow pits into turkey nests and this practice could be utilised as an alternative low cost water supply option where possible. Pumping direct to turkey nests is the preferred option because of the smaller volumes of water lost to evaporation.

Fifty millimetre polythene pipe, buried where possible, can be used to pipe water up to four kilometres in flat country. The distance can be increased by using larger diameter pipes and higher capacity pumps. It is desirable to bury polythene pipe to protect it from physical damage (e.g. grass fires or stock trampling) and because its...
strength is reduced if subjected to elevated daytime temperatures.

4.6 Supply of Stock Water from Tanks

Turkey nests are required as a balancing reservoir between the tank and stock watering troughs. Dimensions for turkey nests providing three days water for various stocking rates are given in Appendix 7. The basic equipment to transfer water from an excavated storage tank to a turkey nest is a pump, with a choice of three energy sources, diesel, wind or solar. The initial cost of a windmill or solar powered pump is high but running costs are low. The low cost and availability of a relatively cheap diesel motor and centrifugal pump makes diesel the preferred option even though running costs are high. The advantages are mobility and ease of maintenance.

5. RECOMMENDATIONS

- The water resources development map can be used to determine the type of water supply most appropriate to a specific area on the Station. In areas where alternative options are available economics will normally determine the final development type selected.
- Groundwater is generally available over much of the station however in situations where surface water flows and soil types are suitable, excavated tanks away from clearly defined drainages, and sited to harvest sheet flow are an alternative option to bores.
- The provision of reliable water supplies with a maximum grazing radius of six kilometres should be a priority, in order to reduce over-grazing and soil erosion.
- Advice should be sought from geotechnical engineering consultants when considering the construction of larger excavated tanks, or from groundwater consultants or the Water Resources Division for detailed bore siting information.

Specific recommendations are considered under three headings: distribution, groundwater, and surface water.

5.1 Water Supply Distribution

In many parts of the V.R.D. over-grazing has resulted in a reduction of ground cover and in places, in soil erosion. Another unwanted result is degradation of pasture quality by allowing unbeneficial species and weeds to become dominant. Apart from the number of cattle present, the distribution of watering points is a major factor affecting grazing pressure. A rule of thumb commonly adopted for planning the location of watering points is that they should be located so that cattle can graze the whole paddock without having to walk more than six kilometres for water. Where possible, tanks or bores should be located to give a maximum spacing of twelve kilometres between watering points. Otherwise the water can be piped to turkey nests or directly to troughs in appropriate locations. The piping of water away from supplies sited in the corners of paddocks may decrease the grazing pressure by keeping the cattle spread over a greater area. (Figure 7). The station has a reasonably good distribution of watering points, except in the northern area. Prospects for either groundwater or surface water supplies in that area are poor however.
SCHEMATIC DIAGRAM SHOWING IMPROVED SIZE OF GRAZING AREA DUE TO PIPING AWAY FROM RELIABLE BORE OR TANK

Fig. 7

Water Resources of Riveren
5.2 Groundwater

Over the station as a whole the prospects for obtaining groundwater supplies are only moderate with a success rate to date of about 40%. In the case of basalt which underlies the larger part of the station most supplies occur at shallow depths. Future drilling should target shallow aquifers. For example instead of drilling one, one hundred metre bore it may be better to limit the maximum depth to thirty metres and then drill three bores if necessary. The chances of success would be improved by locating the sites as far from each other as practical. Drilling deeper than thirty metres is risky because there are usually no indications at the surface of deep water.

5.3 Surface Water

Drainage-line and offstream type excavated tanks are recommended for areas with cracking clay soils at least 3 metres deep. Excavated tanks could also be constructed where there is as little as 2.5 metres of soil but the reliability would be 80% or less and the supply would be confined from four to six months in the Dry. Selection of sites depends on the presence of suitable subsoils. Deepening or enlarging the surface area of existing surface water storages should be subject to satisfactory sub-soil investigations. Site investigations are an essential prerequisite for any construction work. All existing and planned surface water storages (excavated tanks, waterholes, springs etc.) should be fenced and stock watering infrastructure such as troughs, windmills, turkey nests or on-ground fabricated tanks should be provided.

6. ACKNOWLEDGMENTS

The authors would like to thank John and Terry Underwood of Riveren Station for their assistance during the study. The guidance of Mr Peter Jolly, and Mr. Fred Barlow throughout the survey has been much appreciated, as has the efforts of the drafting and GIS staff, Lynton Fritz and Jeff Fong, who produced the maps and figures for the report. Thanks also to Technical Assistants Roger Farrow and Rob Roos who carried out the GPS surveys and to the drilling and pump testing crews. The staff of the Pastoral Branch of the Department of Lands and Housing also provided much assistance in the form of pastoral maps, inspection reports and general advice.

Water Resources of Riveren
APPENDIX 1

STATION BORES

The following table is a list of bores drilled on the station together with selected details about their location, construction and groundwater intersections. More detailed information on many bores is available on request from the Water Resources Division in Darwin. Some of the headings on the table are explained below:

- **BORE RN** A registered number assigned to each bore by the Water Resources Division.

- **AMG EASTING** The east-west coordinates of the bore in metres. It refers to the grid lines on the map.

- **AMG NORTHING** The north-south coordinates of the bore in metres. It refers to the grid lines on the map.

- **DEPTH DRILLED** The total depth of the bore in metres below ground level.

- **CASING** The length of casing in the hole in metres and its internal diameter in millimetres.

- **WATER STRUCK** The depth in metres below ground level at which the main water bearing zone was encountered.

- **YIELD** The amount of water obtained in litres per second by airlifting, usually during drilling of the hole.

- **SWL** Standing water level, the depth below ground level that water rises to in the bore.

- **SLOTS** The depths in metres below ground level between which the bore casing is slotted.

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<th>AMG NORTHING</th>
<th>DEPTH DRILLED</th>
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Water Resources of Riveren
APPENDIX 2

CHEMICAL ANALYSES OF GROUNDWATERS

The following table lists chemical analyses performed on groundwaters on Riveren. See Appendix 3 for an explanation of the main factors which limit water use for stock and domestic consumption.

Water Resources of Riveren
## APPENDIX 2 CHEMICAL ANALYSES OF GROUNDWATERS RIVEREN

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APPENDIX 3

WATER QUALITY REQUIREMENTS FOR STOCK AND DOMESTIC WATER

1. WATER QUALITY STANDARDS FOR STOCK USE

<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>GUIDELINE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH range</td>
<td>5.5 - 9.0</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>8000 mg/L</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>Not more than 75% when total dissolved solids near limit.</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2000 mg/L</td>
</tr>
<tr>
<td>Nitrate</td>
<td>400 mg/L</td>
</tr>
<tr>
<td>Fluoride</td>
<td>5.0 mg/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>300 mg/L</td>
</tr>
</tbody>
</table>

The composition of mineral supplements to stock feed must be considered when stock waters are near to the guideline limits, especially for fluoride and sulphate. Further information is available from the Chief Veterinary Officer, Northern Territory Department of Primary Industry and Fisheries.

2. WATER QUALITY STANDARDS FOR DOMESTIC USE (NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL, AND AUSTRALIAN WATER RESOURCES COUNCIL CRITERIA)

Analyses of water intended for human consumption should lie within the guidelines listed below. Discussion relating to the quality of domestic water should be addressed to the Northern Territory Department of Health and Community Services.

<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>GUIDELINE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH range</td>
<td>6.5 - 8.5</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>1000 mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>400 mg/L</td>
</tr>
<tr>
<td>Sulphate</td>
<td>400 mg/L</td>
</tr>
<tr>
<td>Nitrate</td>
<td>45 mg/L</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.5 - 1.7 mg/L</td>
</tr>
<tr>
<td>Hardness (as Calcium Carbonate)</td>
<td>500 mg/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>300 mg/L</td>
</tr>
</tbody>
</table>

Water Resources of Riveren
PUMPING TEST RESULTS

The results of pumping tests carried out on bores on Riveren are summarised in the following table. More detailed information is available from the Water Resources Division in Darwin.

<table>
<thead>
<tr>
<th>RN</th>
<th>BORE NAME</th>
<th>PUMP RATE (L/s)</th>
<th>PUMP SETTING (m)</th>
<th>BORE DIAMETER (mm)</th>
<th>SWL (m)</th>
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<tbody>
<tr>
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<td>21993</td>
<td>Jump Up</td>
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<td>20</td>
<td>152</td>
<td>10.6</td>
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<td>26799</td>
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<td>35</td>
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<td>6.9</td>
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<td>5</td>
<td>18</td>
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</table>

PUMP RATE - The recommended pump rate in litres per second

PUMP SETTING - The recommended depth below ground level at which intake should be set

BORE DIAMETER - The minimum internal bore diameter in millimetres

SWL - The standing water level in the bore, in metres below ground level, measured immediately prior to the test

Water Resources of Riveren
APPENDIX 5

WATERHOLES ON RIVEREN STATION

1. Mucka Waterhole:

This is a long waterhole on the Victoria River, and is identified as two separate waterholes namely Lower and Upper Mucka waterholes. Each of them supply stock water on a daily basis soon after the wet, to about 1000 head till end of the year. The reliability of the supply varies from 80 to 90% depending on the number of cattle and the severity of the dry. The waterholes dry almost at the end of Dry except for Lower Mucka, which is probably maintained by spring flows. Reliability could be maintained at 90%, if the supply were restricted to seven months soon after the wet.

2. Pelican Waterhole:

Another long waterhole in the Victoria River, Pelican Waterhole supplies 1000 head of stock soon after the wet till end of November or December. The reliability of this stock water supply is between 80 and 90%. Reliability could be maintained at 90%, if the daily supply were restricted to six months soon after the wet.

3. M.C Waterhole:

This is one of the longest waterhole in Victoria River. It too serves 1000 head with a reliability varying between 80 and 90%, depending on stock numbers, and severity of the Dry. Reliability could be maintained at 90%, if the daily supply were restricted to six months soon after the wet.

Water Resources of Riveren
Having determined a catchment capable of supplying stock quality water for the required stock numbers, site investigations must be undertaken to confirm that the proposed tank site is suitable. The site investigation guidelines presented here are based on a very useful booklet entitled "Design and Construction of Small Earth Dams" (Nelson, 1985, Inkarta Press, Melbourne). The key investigation method is to auger a series of investigation holes. In an excavated tank situation this helps to:

- determine the extent of impermeable soils and the presence of any layers which are likely to have leakage problems
- show if there is any impermeable and soft rock present, such as rippable shale
- ascertain whether shallow groundwater is present, and if so, is it suitable for stock
- provide information on the soils to ensure the tank sides will be stable

If an onstream tank is proposed then spillway conditions will also require investigation. If it is too sandy it will erode and wash away or if it is in rock, excavation could be very expensive.

A hand operated 100 mm earth auger capable of drilling to between 5 and 6 metres is the basic tool for the subsurface investigations. Auger holes are sunk in soil to one metre deeper than the tank design depth, with minimum 500 gram samples taken wherever there is a change in soil. A plan of the soil changes down each hole should be kept to compare variations from hole to hole. Excavated tanks require a minimum five test holes, one in the centre and the other 4 positioned at the mid point of each corner slope of the proposed tank (Figure 8). For the modification of an existing waterhole, auger holes are sunk at 50 metres apart along the centre of the bed, and 100 metres apart along the edges of the bed.

The site for proposed excavation must fulfil three main conditions:

- the loss by seepage must be relatively low
- the sides must be stable
- siltting must not be excessive

1. Seepage Loss

In most areas of the plains country the watertable will be deeper than the proposed 4 to 4.5 metre tank depth. Hence leakage of stored water through the sides and base of the tank is possible. A simple permeability test can give an indication of potential leakage from the tank using the series of auger holes used for soil sampling. The following procedure is proposed but is only indicative:

1. Pre-soak each hole for at least 1 hour before starting the test by filling the hole to exactly 0.5 metres below ground level and maintaining it at this level by addition of water.

2. The test involves maintaining this water level (0.5 metres below ground level). The amount of water added to keep the water level is recorded. Continue the test for one day.

If the water added exceeds 30 litres per hour, then the site is too permeable for an excavated tank. If it is between 3 and 30 litres per hour then the area should be
TEST HOLE PLAN FOR
AN EXCAVATED TANK

Fig 8
considered as doubtful and should only be accepted with professional advice. Rates less than 3 litres per hour indicate that leakage will not be a serious problem.

2. Tests on Soil Samples

Soils commonly consist of particles which may range in size from coarse gravels, through sands and silts, to very fine clays. Gravels and sands can be readily identified by appearance and feel and unless they are mixed with finer silts and clays will be prone to leakage. Clays and silts are indistinguishable when dry. While clay is one of the most useful soils in dam building, silt, when wet, is the most troublesome. It tends to be unstable in the presence of water, often collapsing when saturated.

Generally a favourable site investigation result will confirm the presence of non-dispersive clays that bind together any coarser particles to create a water holding material. Accurate classifications of soil types can be undertaken by sending at least 100 gram of sample to the Land Conservation Branch, Department of Lands Planning and Environment and these provide a very good indication of soil suitability. However simple field tests can give a good feel for the likely behaviour of the soils.

1. A simple test to differentiate clay from silt is to moisten the sample and feel it. Clay should be sticky. Pinch a sample between the thumb and forefinger; if it is clay it should be possible to form a flexible ribbon about 1.5 mm thick and at least 40 mm long.

2. If the presence of clay is established then the water holding potential of the soil can be tested using the "bottle test". The bottom of a 1.25 ml plastic drink bottle is cut off. The bottle is inverted and one-third filled with the soil to be tested. The bottle is filled with water. If no water seeps through the soil in 24 hours, it has good water-holding properties.

3. All clays should be tested for dispersion. Some clays break down in water to form a suspension of clay particles throughout the water. This is dispersion and has been the cause of many dam failures. To test for dispersion take 5 to 10 grams of air dried soil crumbs and drop them into 100 ml of distilled water in a cup. Allow it to stand for at least one hour without shaking. If the water appears cloudy then dispersion has occurred and special care will be needed if building tanks in these materials. The presence of deep erosion gullies suggests markedly dispersive soils and these sites should be avoided.

If site investigations show that there is likely to be problems with any of these factors then professional advice should be sought, and remedial measures may be possible. However it may be necessary to abandon the proposed site.
CONSTRUCTION DETAILS OF EXCAVATED TANKS, TURKEY NESTS AND MODIFIED WATERHOLES

Assuming preliminary investigations (Appendix 6) have shown the suitability of a site for a specific structure then construction can begin. No matter how good the design, poor construction methods can lead to a less than perfect structure.

1. Excavated Tanks

The site is first cleared of vegetation and the planned tank laid out on the ground using marker pegs. Excavation is commonly carried out using scrapers or bulldozers. If the tank is in an area with some slope (say greater than 1 in 100) excavated material can be used to construct bunds around three sides of the excavation to increase its storage capacity. The bund should have a minimum berm width of 5 metres (Figure 6). Topsoil with potential for leakage must be removed down to an impervious layer before the bund is built, and compaction should be undertaken using the available machinery. The ideal time to achieve optimum compaction is early in the Dry when soils are still slightly moist.

Three sides of the tank are excavated with a slope of 1 in 3, and flow enters the tank through the side with a mild slope, as low as 1 in 10. The inflow side may be rubble packed to prevent erosion. Where the excavation is in rock, with little chance of erosion, the inlet batter may be increased to 1 in 4, to decrease the volume of material to be removed. The recommended slopes allow for machinery to enter the tank, excavate, turn and exit with ease. For offstream excavated tanks catch drains can be constructed, e.g., using a tilted grader blade, to direct an increased volume of sheet flow towards the tank.

2. Modifying Waterholes

Modifying a waterhole usually means constructing a narrow excavated tank within the waterhole to increase its storage capacity. Site investigations are critical. If the subsoil is impermeable, non-dispersive, and there is no rock within two metres depth then excavation should be possible using a scraper. The presence of rock will usually require the use of rippers for excavation. The longitudinal batter could be 1 in 3 or less, while the cross sectional batter should not be more than 1 in 2.

3. Turkey Nests

The current design and construction techniques for turkey nests are adequate although special attention should be paid to:
> removal of leaky topsoil from the base before construction;
> the selection of a non-dispersive soil construction material (Appendix 6);
> compaction at optimum moisture content. This can be achieved if construction is undertaken early in the Dry while soil is still moist. Every 100 mm layer of loose soil should be compacted.
For three days water supply from a turkey nest the following dimensions are recommended:

<table>
<thead>
<tr>
<th>NUMBER OF CATTLE</th>
<th>INNER DIAMETER AT BASE (metres)</th>
<th>INNER DIAMETER AT TOP (metres)</th>
<th>HEIGHT (metres)</th>
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<tr>
<td>500</td>
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<td>16</td>
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</table>

These figures are based on sides with a 1 in 2.5 slope.
GLOSSARY

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

BATTER   Slope expressed as a ratio of horizontal to vertical distance.

BERM     Flat area between excavated area of tank and bund.

BORE     Small diameter hole constructed with a drilling rig, and down which a pump is lowered to extract groundwater.

BUND     Bank, constructed of compacted fill, used to contain water.

DEMAND   The volumetric flow rate required for stock watering, therefore the rate at which water would be supplied if available.

DRAINAGE-LINE TANK  Excavated tank built in an area which does not have a defined creek.

GROUNDWATER  Water contained in rock below the water table.

OFFSTREAM TANK  Excavated tanks built near creeks, and connected to the creek by a channel to tap the creek flow.

ONSTREAM TANK  Excavated tanks built across a well defined stream.

RELIABILITY  The frequency at which a tank would be able to supply the annual stock water demand, eg. 90% reliability means that the tank should be able to supply annual stock demand for on average every nine years out of ten.

Water Resources of Riveren
**SPILLWAY**
A structure designed to overflow excess water out of a dam.

**SPILL TAIL CHANNEL**
A channel built downstream of the spillway to direct excess water back into the creek.

**STANDING WATER LEVEL (SWL)**
The level, below the ground surface, to which groundwater will rise in a bore or well.

**STORAGE CAPACITY**
The volume of water that can be stored in a tank up to its full supply level.

**TOTAL DISSOLVED SOLIDS (TDS)**
A measure of water salinity based on the quantity of solids left after evaporation of a litre of the sample.

**WATERTABLE**
The surface resulting when the standing water levels in adjacent bores in the same aquifer are connected.

*Water Resources of Riveren*