POWER AND WATER AUTHORITY
WATER RESOURCES DIVISION

WATER RESOURCES SURVEY OF THE
WESTERN VICTORIA RIVER DISTRICT

LEGUNE STATION

REPORT 31/1995D
S. J. Tickell and L. R. Rajaratnam
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WATER RESOURCES SURVEY OF LEGUNE STATION NORTHERN TERRITORY

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LIST OF ABBREVIATIONS

km	-	kilometre
L/s	-	litres per second
m	-	metre
m^3	-	cubic metre
mg/L	-	milligrams per litre
ML	-	megalitre (one million litres)
mm	-	millimetre
μS/cm	-	microsiemens per centimetre
pH	-	acidity and alkalinity index
TDS	-	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

SUMMARY

The accompanying Water Resources Development Map can be used as a guide to determine the type of water supply most appropriate to specific areas of the station. On the black soil plains (the main grazing area) the best options for future water supply developments are considered to be excavated tanks, sited to capture wet season sheet floods. The reliability of existing tanks can be improved in many cases by deepening where appropriate. All existing and planned surface water storages including excavated tanks, waterholes and springs should be fenced and stock watering infrastructure provided. An alternative to excavated tanks is to pipe water from bores situated on higher ground adjacent to the plains. Groundwater beneath the plains is generally too salty for stock.

Legune has an adequate distribution of watering points in most areas but from the point of view of spreading grazing pressure more evenly, some sections of the station ,especially those more remote from the homestead could benefit from additional watering points.

1. INTRODUCTION

This project was initiated by the Victoria River District Conservation Association (VRDCA). The 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.

Legune station covers an area of 3089 km^2 and is located between the Western Australian border and the lower reaches of the Victoria River. Road access is only possible through Western Australia via Kununurra (Figure 1). During much of the wet season the road is impassable and the homestead situated on the eastern side of the property can only be reached by air.

The availability of stock water is the major influence on stock management. Nearly all of the annual rainfall, which averages 1065 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 when temperatures are warm. During the Wet, when the streams flow, much of the low lying country is inundated. Recharge to groundwater aquifers occurs at this time. During the Dry, evaporation rates of water bodies such as dams or lakes are between 5 and 9 millimetres per day (average about 7 mm per day or 2.6 metres per year). This ensure that water levels in creeks, dams and tanks decline rapidly. Air temperatures are high throughout the year. The average monthly maxima range from about 30.3 degrees in July to 38.5 degrees in November. The corresponding average monthly minima are 12.9 and 25.3 degrees.

Current stock management is based on water availability. At present the station carries about 18,000 head of cattle. Bores supply approximately 85% of their water needs, the remainder coming from dams and waterholes. Groundwater is the major water source, particularly in the Dry. Thirteen bores are used, normally in conjunction with turkey nests which act as temporary storages. During the Wet and the early Dry, surfacewater is extensively used, but as the Dry progresses, these sources become depleted and more reliance is placed on groundwater. None of the man made storages normally last until the end of the Dry. A spring and a deep waterhole however are successfully exploited throughout the year. The station's main dams are excavated tanks, four are located on flat areas with ill defined drainage and one is located along a well defined watercourse. Three turkey nests are currently supplied with water from their borrow pits. A gully dam has recently been constructed in gently undulating country.

The station can be classed into three broad landform types, rugged hills and ranges, lateritic plains and low hills, and coastal and alluvial plains (Figure 2). Most pastoral development is undertaken in the latter areas because they support better pasture and are more accessible.

The ranges cover the southeastern part of the station where they rise abruptly out of the plains to a maximum elevation of approximately 280 metres above sea level. They are steep and rocky, supporting low open woodland and sparse grassland. Numerous short streams dissect the ranges, with many deep valleys and gorges. Soils are thin and stony.

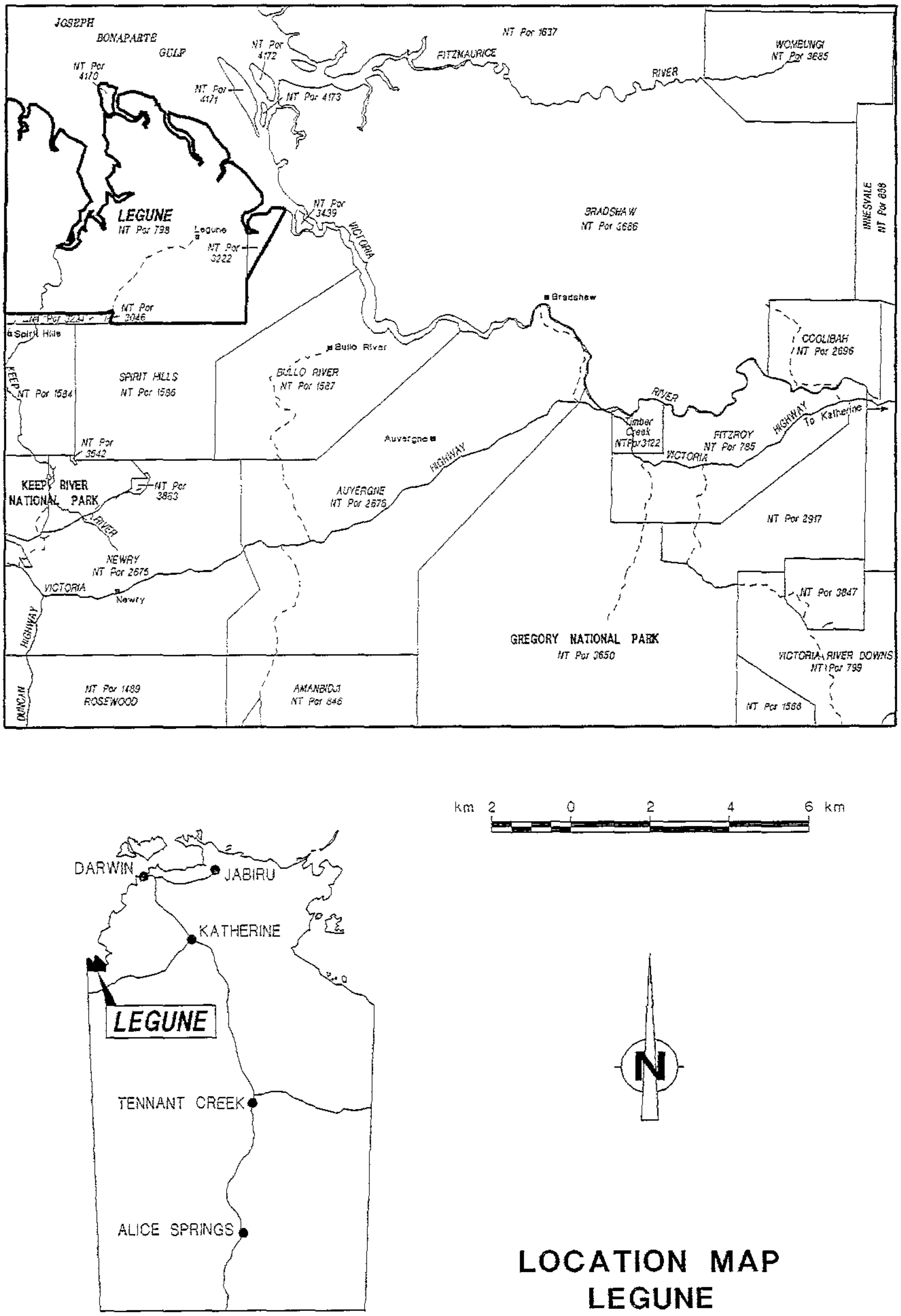
TABLE 1

CLIMATIC AVERAGES - LEGUNE STATION

	RAINFALL (mm)	RAIN DAYS	DAILY MINIMUM TEMPERATURE (°C)	DAILY MAXIMUM TEMPERATURE (°C)
JANUARY	281	14	24.7	35.6
FEBRUARY	274	12	24.5	34.3
MARCH	212	10	23.7	34.8
APRIL	30	1	20.3	34.9
MAY	10	0	17.2	32.6
JUNE	1	0	13.5	30.3
JULY	3	0	12.9	30.3
AUGUST	0	0	15.3	32.7
SEPTEMBER	4	1	19.6	35.6
OCTOBER	24	3	24.1	37.6
NOVEMBER	87	5	25.3	38.5
DECEMBER	139	9	24.8	36.9
TOTAL	1065	55		

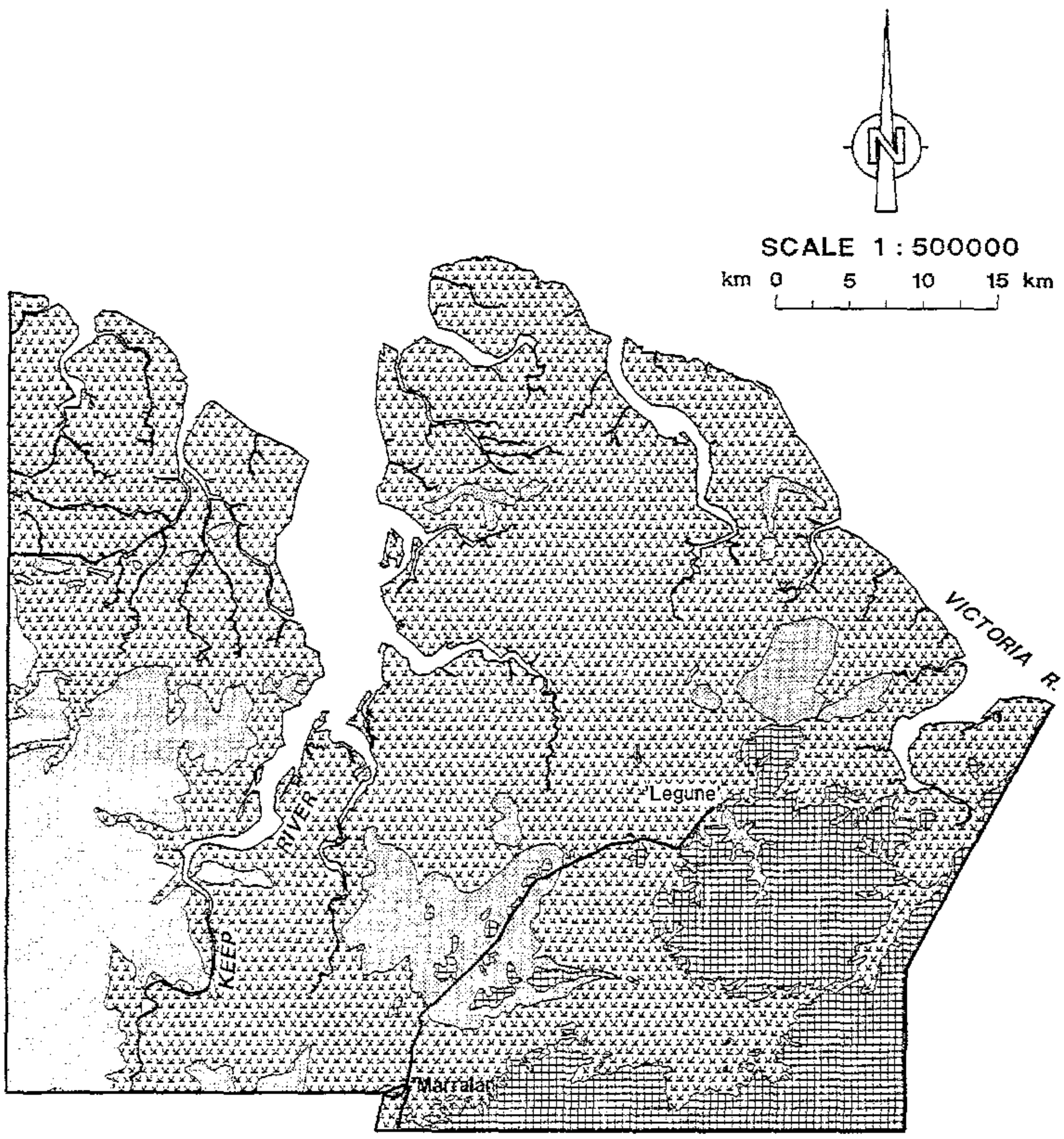
NOTE: *: Temperatures noted are from Auvergne Homestead.

The lateritic plains and low hills flank the Keep River plains but also occur as isolated patches in the north and northeast. They are mainly formed on flat lying strata of soft sandstone. A laterite(ironstone) cap is developed on the sandstone but minor stream erosion has partially removed it, resulting in undulating topography in many areas. The plain lies at elevations of between 20 and 40 metres above sea level ,with isolated hills such as the Weaber Range rising up to 80 metres above the plain. The area supports woodland vegetation. Drainage on the laterite plain is often poorly developed, probably due to the permeable nature of the soils and the



LOCATION MAP
LEGUNE

Fig. 1



LEGEND

Coastal and alluvial plains

Laterite plains and low hills

Rugged hills and ranges

LANDFORM MAP OF LEGUNE STATION

Fig. 2

underlying sandstone. Deep sandy soils predominate with minor clayey lateritic profiles present in places.

The coastal and alluvial plains comprise the largest part of the station. Saline coastal flats form a broad fringe on the seaward edge of the plains and they are subject to tidal inundation. Large areas are bare mudflats while other parts contain patches of salt tolerant shrubs and grasses. Above the level of the highest tides are extensive plains characterised by black cracking clay soils. Apart from a few isolated low hills they are flat and featureless, varying in elevation from 5 to 15 metres above sea level. The plains are covered in grasslands with patches of low woodland and shrubland. The Keep River, Sandy Creek and a few minor creeks pass across the area and have cut channels which are up to 10 metres below the level of the adjacent plains. They are tidal along a considerable section of their lower reaches. The plains themselves have poor drainage , much of them being subject to sheet flooding during the wet season. In places numerous lakes are present and they contain water at least into the early part of the dry season. The area of alluvial plains known as "Bluey's Pocket" has a slightly higher gradient, sandier soils and is drained by numerous small streams.

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 Legune station. The map was made by combining information on existing developments (dams, bores etc.) with information on groundwater occurrence, topography and soil types. Local conditions, such as soil types can vary considerably, so the map should not be taken as a definitive guide to cover every situation. Rather it is a broad scale map which is 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 map refer to the legend entitled "Water Resources Development Options". The various "preferred options" listed there fall into four types:

-areas which are unsuitable for artificial water supplies such as surface water storages or bores (options 1 and 2).
-areas in which surface water storages are the best option (options 3 and 4).
-areas in which groundwater is the best option (option 5).
-areas in which surfacewater and groundwater may both be viable options (options 6 and 7).

Some of the main features of the map are:

-the areas used most for grazing, the black soil plains, are generally only suitable for the development of surfacewater supplies. Local groundwater is saline. Usable groundwater found in adjoining higher country can be piped to the plains.
-large areas of the station are unsuitable for water supply developments either due to rugged terrain or because of periodic tidal inundation.

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**, one of the two small side maps on the accompanying map of Legune station.

Technical information on water bores is shown in Appendix 1. Furthur 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.

Stock water is presently obtained from about thirteen bores on Legune. Numerous unsuccessful bores have also been drilled over the years. Failures have been due to either an insufficient supply of water or because the groundwater was too salty.

Rock type is the main factor which determines groundwater availability and the three yield zones shown on the map (0 to 0.5, 0.5 to 5 and more than 5 litres per second) reflect different rock formations. 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 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 obtain lower yields. 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 unsatisfactory for the scale of the present day pastoral operations.

High salinity waters, unsuitable for stock, occurs under much of the black soil plains. The salt water originates from marine sediments and from inflows of seawater along tidal sections of the rivers and creeks. Fresh groundwater in those areas is restricted to the immediate vicinity of isolated hills which protrude through the plain, for example Flapper Hill and Bevan's Bore hill. The soils there are more permeable and allow fresh water to replenish the groundwater. The black soils on the other hand are very tight and allow relatively little water to seep down. The patches of fresh groundwater are not only surrounded by salt water but probably also sit on top of it. Occasional checks on bore water salinity should therefore be made to ensure that salt water is not being drawn in.

Each of the three yield zones on the groundwater map are now described:

3.1 Areas with yields 0 to 0.5 L/sec (brown zone).

This zone includes the hills and range country in the southeast part of the station. The rocks are mainly hard sandstones and siltstones. Aquifers are formed locally, usually at depths shallower than 50 metres where the rocks are sufficiently fractured. More than half of the bores drilled in this area to date have not produced sufficient quantities to supply a stock bore. The maximum airlift yield reported by drillers is 3 L/s in RN 29228. Airlift yields in this type of aquifer are likely to overestimate the actual capability of a bore. For example New Bottle Tree bore (RN 27129) had an estimated yield of 2.25 L/s after three hours of airlifting. When test pumped however a safe yield of only 0.2 L/s was determined (Appendix 4).

Prospects for successful bores can be improved by siting bores along major fractures identified on aerial photographs or satellite images. Valleys cutting into the hills may also indicate the presence of water bearing fracture zones. The narrow area of this zone located between the blue and yellow zones on the groundwater map comprises a shale formation which is unlikely to contain any significant aquifers.

If any water drilling is contemplated in this zone in the future, the following points should be considered:

- groundwater beneath the black soil plains is likely to be too salty for stock.
- groundwater beneath the "Bluey's Pocket" area is untested but it may be of useable quality in places.
- the chances of obtaining sufficient water are much less than 50% but can be improved by careful site selection.

3.2 Areas with yields 0.5 to 5.0 L/s (blue zone).

This zone runs northeast - southwest and flanks the main road. It is largely untested but the types of rocks seen in outcrops and in mineral exploration boreholes suggests that yields of between 0.5 and 5.0 L/s should be available. Two main rock types are present, sandstone and limestone. Aquifers are likely to be within 50 metres of the surface and will be locally developed, dependant on the presence of fractures. In the case of limestone, aquifers may be more widespread due to the presence of solution cavities. Sinkholes in this area indicate that the limestone is cavernous and so may locally have potential for yields above 5 L/s.

This zone extends to the northeast beneath the black soil plains where it is likely to contain saline water. Local fresh water may occur in the immediate vicinity of hills which protrude through the plain.

Several cased mineral exploration bores are present in this zone. If they are to be used to supply water for human consumption it would be advisable to have the water analysed for heavy metals, particularly lead. Unacceptable lead levels have been found in groundwater from similar rock formations at Sorby Hills, just southwest of the station.

3.3 Areas with yields more than 5 L/s (yellow zone).

The main aquifer in this zone is in an extensive sandstone. It is exposed in places along the bed of the Keep River where it can be seen to be soft and porous. Another aquifer is present beneath the Keep River plains, consisting of loose sand and gravel beds which are deposits of former courses of the Ord and Keep Rivers. These sands and gravels overlie the main sandstone aquifer.

Quantities sufficient for stock supplies should be available throughout this zone. The main limitation on it's use are the high groundwater salinities beneath the plains. As with the other zones useable water in the plains area is restricted to isolated hills. In the southern part of the Keep River plains the groundwater is brackish but still suitable for cattle (e.g. 3088mg/L TDS in Long Grass Bore). Large areas of slightly higher sandy country flank the southern margins of the plain. Water quality in these areas is generally very good. These areas could be considered for the construction of high yielding bores (more than 5 L/s) which could supply several remote watering points via pipelines.

A problem sometimes encountered in constructing bores in this sandstone is that it is fairly soft and prone to disintegrate around the bore following extended periods of pumping. If slots in the casing are cut too wide, fine sand can enter the bore damaging the pump and eventually blocking the bore. The finest possible slots are recommended to avoid this. An extra length of slotted casing can be added to compensate for the reduced intake area. In the case of high yielding bores designed to supply several remote watering points, the use of stainless steel bore screens is recommended. Although the sandstone is soft, it is generally stable enough to be drilled with the air/rotary technique. The sands and gravels below the Keep River plains however are completely unconsolidated and it would be advisable to use drilling mud instead of compressed air to keep the hole open.

4. SURFACEWATER

Surface water flow in the creeks, rivers, and the floodplains is largely confined to the wet season. However replenishment of some waterholes and creek flows during the Dry are due to spring flows. An effective annual evaporation rate of about 2.6 metres is responsible for the subsequent rapid loss of stored water from tanks and waterholes. During the average Wet, flow of the Keep River, Victoria River, and minor streams are often accompanied by sheet flow over much of the low lying inland plains country. After the Wet, all drainages above the tidal influence deplete to form unconnected waterholes, the majority of which are dry by about October. 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. In a paddock holding 500 head the requirement is to hold 9.1 megalitres (million litres) of water for stock supply (50 litres/day/head) after allowance is made for evaporation losses.

For it's stock water supply from surface water, Legune Station is largely dependent on excavated tanks, dams, temporary waterholes and billabongs. About 15% of the stock water demand on the station is supplied from natural and artificial surface water storages.

The region has been divided into five zones showing suitability for surface water development for stock watering. They are based on soil type , 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 of Legune.

4.1 Surface Water Storage Types

Three types of excavated tanks are suitable for the plains, onstream tanks(Plate 1), offstream tanks, and drainage-line tanks(Plate 2), the latter being the preferred option. On Legune the depth of excavated tanks should be 3 to 3.5 metres, depending on subsoil types. As the depth of the tank increases beyond three metres, it's reliability increases. Details of the station's key surface water storages and an assessment of their capabilities are given in Appendix 5.
The majority of the existing man made reservoirs are shallow excavated onstream tanks with a surrounding bund on three sides, made from the excavated material and open on the upstream side. From the top of the bund these tanks are about 3 to 4 m deep, but with a maximum excavated depth of only 1.5 to 2.0 metres The existing design and construction of these tanks has resulted in the following problems:

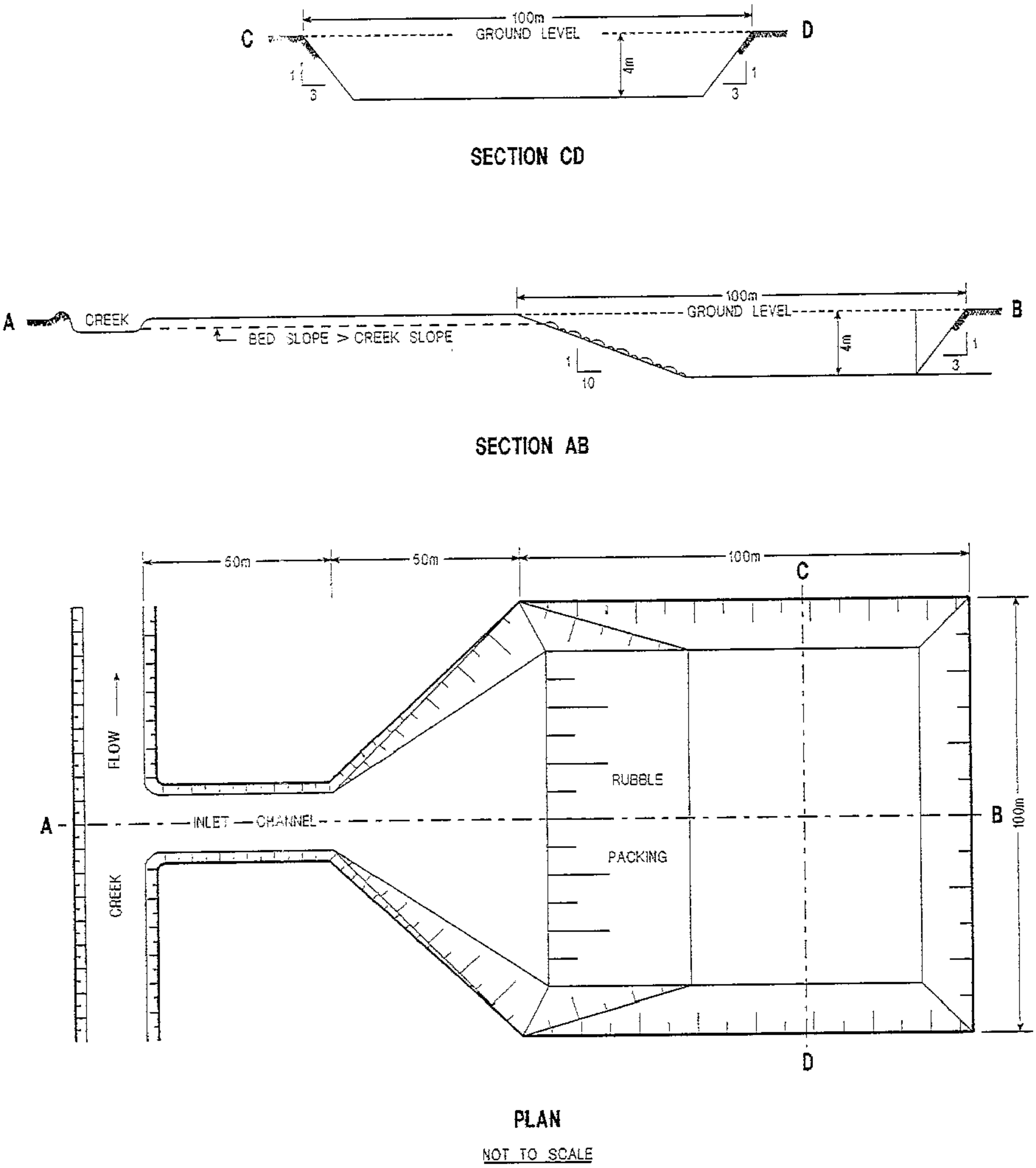
(1) rill erosion of the bund and silting of the tanks .

(2) inadequate spilltail channels do not direct water away from bund walls prompting further erosion .

Regular maintenance is required before the next Wet to correct damage due to these problems. The current excavated tank design does not give sufficient storage capacity for cattle requirements, due mainly to evaporation losses and to a lesser extent leakage.

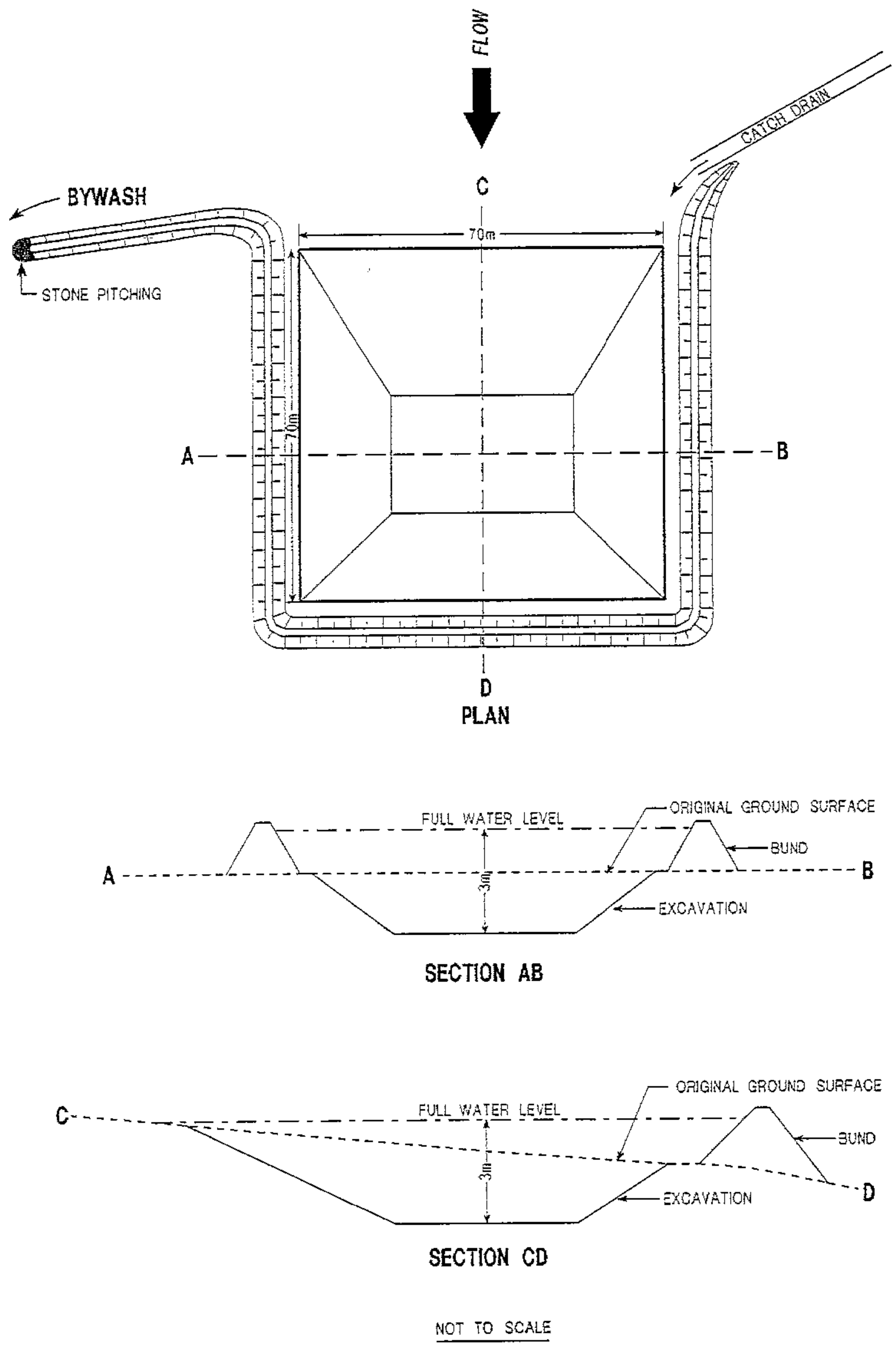
The onstream excavated tank requires a high standard of design and construction and is prone to erosion or silting because of its location in a fast flowing main stream channel. The offstream design (Figure 3) reduces these problems by using a man-made channel to divert water from a natural stream to the tank. This is an improvement on the onstream design, but has excessive excavation costs since 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 4) is an excavated tank constructed in flat to moderately sloping areas where there are no clearly defined creek systems. Weaner dam is an examples of this type of tank. The tank itself is of the same design as the offstream one, but without an inlet channel. It is excavated in a drainage area which does not have a defined creek system and water may be directed towards it using catch drains or wing walls. Sheet flow on the plains, with its low silt load, may be harvested in this manner. This design is most suitable for Legune and has been used successfully on Auvergne and Bradshaw Stations in the same situation.



TYPICAL OFFSTREAM EXCAVATED TANK

Fig. 3



TYPICAL DRAINAGE-LINE EXCAVATED TANK

Fig 4

Another type of dam, the gully dam (Plate 3) is suited to gently undulating country and consists of an embankment built across a drainage line. Bakers Dam, built last year, is the only gully dam on the station . This was constructed without any design or appropriate construction techniques. The two spillways were not sufficient to discharge the floodflows and they were scoured by more than 0.5 metres during this wet in January 1995. The dam filled up to 0.7 metres below the dam crest level. 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 hilly country on Legune may not be possible due to the thin permeable soils and permeable sandstone bedrock. Areas where soils are clayey may be locally suitable for gully dams. The minimum average depth of the dam should be 4 metres in order to compensate for the high evaporation. 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.

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 flat alluvial plains on the **Surface Water Resources Map** cracking clays extend to a depth of up to 4 metres in some areas and are suitable for excavated tanks. Areas mapped as gently sloping 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 hilly country if clayey soils 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 an geotechnical consultant. For drainage-line storages a minimum catchment area of 1 km^2 is required. Other types of excavated tanks require a minimum catchment area of 1.5 km^2.

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 the excavated tank are determined by the stock numbers to be watered for a whole year (stock numbers will be higher if the tank is utilised for only part of the year). This in turn is dependent on the carrying capacity of the paddock, usually varying between 250 and 800 head (ie. a requirement of between 4.5 and 14.6 megalitres per year when based on 50 litres per head per day).

The larger the catchment, the more runoff that can be expected to be captured by a tank. As for drainage-line tanks, catchment sizes between 1 km^2 and 2 km^2 should supply between 300 and 900 head respectively, with 90% reliability (ie. for 9 years out of 10), using the proposed drainage-line storage design. An offstream tank with a catchment size range of between 2 and 4 km^2 should supply between 300 and 1000 head of cattle, with 90% reliability.

The basic design for a typical drainage-line tank is shown in Figure 4 and dimensions of 70 x 70 x 3 metres are recommended for stock numbers up to 400. Dimensions of 100 x 100 x 4 metres are required for stock numbers up to 900, depending on the area of the catchment. A minimum tank depth of 3 to 4 metres is required to allow for an annual 2.6 metres water loss due to evaporation.The basic design for a typical offstream tank is shown in Figure 3 and dimensions of 100 x 100 x 4 metres are required for stock numbers up to approximately 1000. The design of excavated tanks are covered in more detail in the internal Water Resources Division Report No 19/1995D, entitled " Surface Water Storage Potential - Legune Station".

Construction is covered in more detail in Appendix 7. 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 (as at Weaner Dam). Excavated volumes are large for the proposed design dimensions (approximately 10,000 m^3 for the smaller tank, and 27,000 m^3 for the large) so construction costs will be high. Cost will also be influenced by ground conditions.

4.4 Waterholes and Springs

Natural waterholes are present during the Dry, in depressions in stream and riverbeds. Some of the waterholes , such as Alligator Spring waterhole never dry as they are fed by springs. The available capacity of the waterholes could be increased by excavation of the base (Appendix 7), but only where site investigation proves that this will not result in leakage. A shale base could be excavated without fear of leakage, however the region is underlain largely by sandstone which is not water tight. Waterholes in the hilly country may be deepened, provided the excavation is confined to cracking clay soils. The storage capacity of a well confined waterhole with high banks could be increased by construction of a bund at its downstream end.

Springs usually occur on hill slopes and in river valleys. Piping water from springs to areas where groundwater or surface water are not available may be an option in some situations. Knapp spring in Legune is being exploited for stock watering. If a spring is found to have more than 2 litres per second flow at the end of dry, it should be sufficient to supply a turkey nest designed to store three days supply of stock water for 500 head of cattle.

4.5 Piping of Surface Water

Surface water has been piped from borrow pits into turkey nests (Plate 4) 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 pipes to protect them from physical damage (eg. grass fires or accidental ploughing) and because their strength is reduced if subjected to elevated daytime temperatures. Burial, to protect from fire, stock trampling, etc., is easy where surficial materials allow excavation using a tilted grader blade, but is not possible in areas of exposed rock.

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

1. The water resources development map should 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.
2. Excavated tanks away from clearly defined drainages, and sited to harvest sheet flow are considered the best option for new sources of stock water for most of the plains area. Piping of water from reliable supplies (bores, waterholes and springs) in adjacent areas is also an option.
3. The provision of reliable water supplies with a maximum grazing radius of six kilometres throughout the good pasture of the plains should be a priority, in order to reduce over-grazing and soil erosion.
4. 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 5).
Legune has a reasonably good distribution of watering points, particularly in the eastern areas, out from the homestead. More remote places have fewer watering points and areas such as Bevans and Nelson Point paddocks may be appropriate sites for creating new watering points by piping from new or existing sources.

5.2 Groundwater

The best prospects for reliable groundwater supplies are in the areas underlain by the soft sandstone formation. Under the plains the groundwater is generally too salty for cattle but usable water can be obtained from the adjoining more elevated sandy country. High yielding bores capable of supplying several remote watering points can be constructed in these areas. Isolated hills which protrude through the plains are underlain by good water but care must be exercised in those situations not to pump at too greater rate and draw in the surrounding salt water. A zone of limestone and sandstone running between Bundaburg Bore and Marralan Community is also prospective for stock supplies but potential yields and chances of success are not as high as in the soft sandstone aquifer.

5.3 Surface Water

Drainage-line and offstream type excavated tanks are recommended for areas with cracking clay soils. Selection of sites depends on the presence of suitable sub-soils. Gully dams may be locally suitable in undulating country but site investigations and proper design and construction methods are essential. 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

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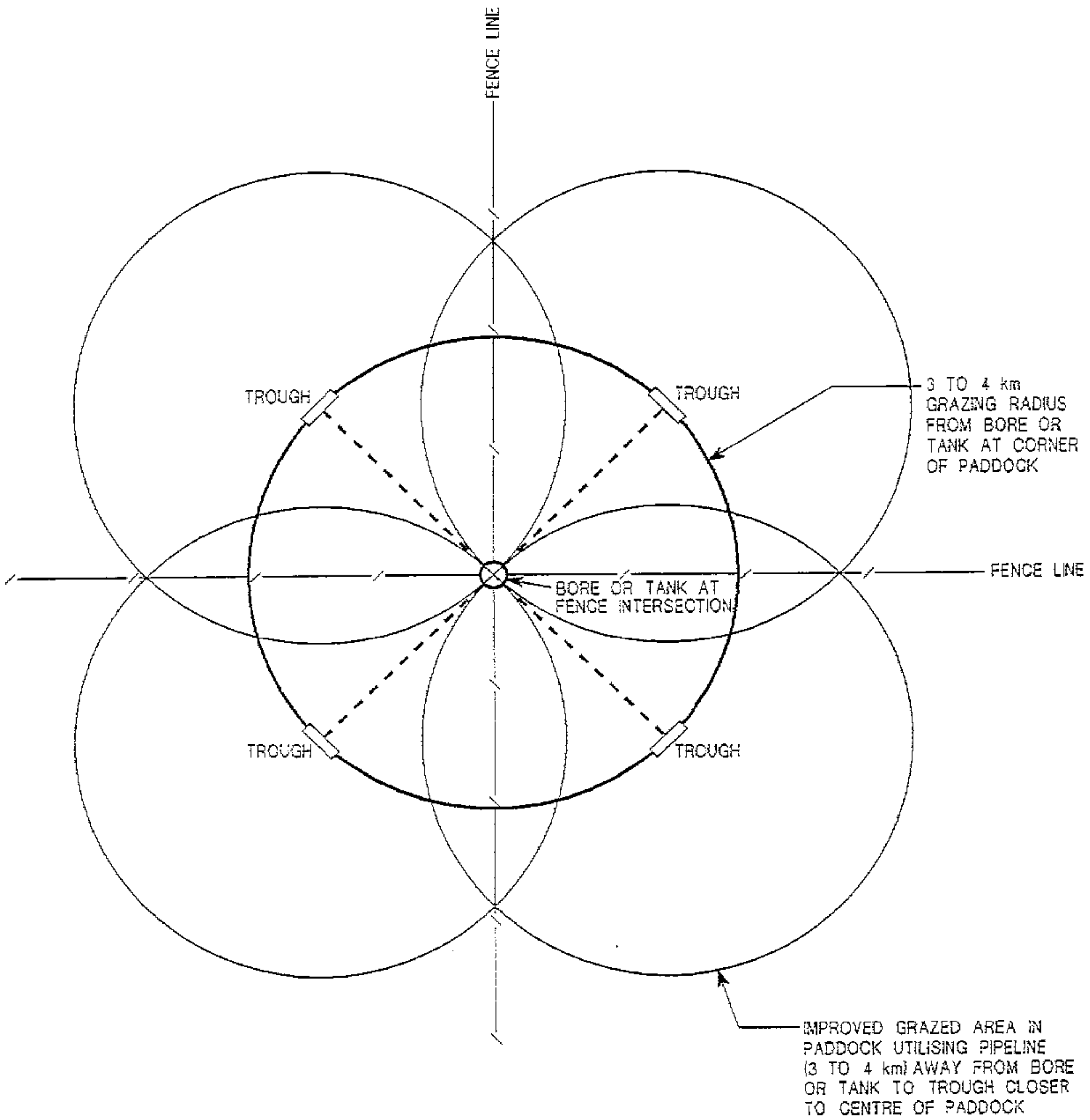


SKETCH SHOWING IMPROVED SIZE OF GRAZING AREA DUE TO PIPING AWAY FROM RELIABLE BORE OR TANK

Fig. 5

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.

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

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

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

-CASING The length of casing in the hole in metres and it's internal diametre in millimetres .

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

-AIRLIFT 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.

APPENDIX 1 STATION BORES LEGUNE STATION

BORE RN	STATUS	EASTING	NORTHING	LOCAL NAME	COMPLETION DATE	Depth(m)	Casing depth(m) xdiam(mm)	Depth struck(m)	Airlift yield(L/S)	SWL(m)	Slots(m)
4118	Capped	548300	8318100		2/11/63	120.4	11x193		0.4		
4761		539200	8323000			15.5					
4950	Capped	527600	8318100		8/27/65	304.8	50.6x142	24			
5021	Capped	542609	8322961	FLAPPER HILL BORE	9/14/65	182.9		17.3	6.3		
5036	Capped	527610	8318100		8/29/65	18.3	18.3x193		5.0		
5043	Equipped	552427	8324408	BOTTLE TREE BORE	9/27/65	61	7.9x193	61	3.8		
5044	Capped	526600	8326200		2/10/65	25.9	19.2x193		5.0		
5133	Capped	549100	8319100		9/21/65	71.9	3.4x193	51.8	0.4		
5135	Capped	539000	8335000			39.6	39.6x142	39.6	1.5	5.5	30.5-39.6
5147	Equipped	533203	8319249	NELSONS POINT BORE	9/13/65	61	61x203	19.8	seepage		40.5-61
5180	Capped	549706	8317336		10/24/65	36.6	32x193	36.6	1.3		
5181	Capped	516600	8305000								
5182		543700	8323650			4.3					
5313	Capped	536435	8314775		6/17/66	28	28x152	19.8	1.3	19.5	
5484	Capped	548600	8316400		6/30/66	22.3	21.6x142	15.2	1.0	20.7	
5520	Capped	547576	8326556		11/7/66	18.3	18.3x142	8.8	1.5	8.5	12.2-18.3
5521	Capped	552900	8330055		7/20/66	38.1	38.1x142	34.1	1.9	14.6	
5542	Capped	526370	8313308		9/17/66	39.2	39.2x142	24.3	1.3	8.8	27.4-38.4
5599	Capped	531467	8304677		4/10/66	40.2	40.2x142	24.3	0.8	9.4	34.1-40.2
5608	Abandoned	524100	8313300		7/30/66	24.4		13.1	1.9	5.8	
5609	Capped	535400	8305100		6/9/66	35.1		35	0.0	10.6	
5665	Abandoned	540800	8335800		12/10/66	25.9					
5666	Capped	541800	8332100		10/15/66	24.4		9	0.3	0.3	
5669	Abandoned	518900	8306800		10/18/66	18.3		7.3	2.5	7.3	
7859	Capped	517100	8312550		6/13/72	21.3	15.2x142	15.6	0.5	10.6	
7860	Capped	517100	8308900		6/13/72	35.1	35.1x142	35	12.6		
7861	Capped	517100	8304000		6/13/72	24.4	15.2x142	15.2	2.5	8.7	
7862	Capped	513500	8304000		12/6/72	27.4	21.3x142	21.4	1.5	10.6	
23870	Abandoned	526700	8298300		11/19/85	36.2					
23871	Abandoned	527000	8298500	MARRALIN COMMUNITY	11/19/85	74.8					
23872	Capped	526537	8298824	MARRALIN COMMUNITY	11/20/85	48.2	48.2x168	31	3.0	5.3	29.9-42.2
23873	Equipped	526516	8298803	MARRALIN COMMUNITY	11/21/85	39	39x168	26.9	2.7	6	27-36.5
25201	Capped	511950	8300550	LONG GRASS BORE	7/28/88	42	42x152	18	4.2	11.4	24.5-35.5
25202	Equipped	536434	8314740	BUNDABURG BORE	1/8/88	36	29x152	27	2.0	19.1	28-30
27012	Abandoned	547700	8316050		2/6/90	60					
27013	Abandoned	552800	8322400		5/27/90	60					
27014		542000	8331800		5/31/90	20		17	3.5	5	
27015	Equipped	526398	8313318	OSMANS BORE	5/24/90	37		31	6.5	9	
27016	Equipped	552900	8330055	STEELES BORE	5/28/90	45		27	4.8	14.6	27.5-45.5
27017	Equipped	547546	8326630	SWEETWATER BORE	5/28/90	21		15	5.5	8.8	15-18
27018		552800	8321200		5/27/90	45					
27019		553250	8324300		5/29/90	97					
27020	Equipped	552683	8325894	RAINBOW BORE	5/30/90	45		33	8.5	14.9	33-45
27021		541050	8330100		5/31/90	15					
27022	Equipped	531331	8304711	LINDENS BORE	3/6/90	45		25	2.3	19	33-45
27128		549850	8326400		7/17/90	30		24	6.0	12.6	18-30

APPENDIX 1 STATION BORES LEGUNE STATION

BORE RN	STATUS	EASTING	NORTHING	LOCAL NAME	COMPLETION DATE	Depth(m)	Casing depth(m) xdiam(mm)	Depth struck(m)	Airlift yield(L/S)	SWL(m)	Slots(m)
27129	Capped	552435	8324408		7/18/90	68		39	2.3	18.3	56.5-68.5
27130	Abandoned	542701	8316882		7/19/90	90		87	3.0	17	
27802		514545	8313402	BEVANS BORE	7/14/91	45		28	3.0	21	30-36
27803	Equipped	524906	8307324	ARCHIES BORE	7/17/91	37		17	4.5	12	25-31
27804		524850	8306200		7/15/91	45		22	0.8	14	
27805		540900	8316000		7/15/91	22		18	2.0	7.5	
28621	Abandoned	542640	8322950		6/10/92	36		5	2.0		
28622	Capped	520203	8301366	SNOWS BORE	5/10/92	45		14	4.0	9	39.5-45.5
29226	Capped	511274	8311210	ALGIES BORE							
29229	Equipped	511563	8306640	GREEN SWAMP BORE					1.5		
29230	Equipped	504097	8322410	SKULL CREEK BORE							
29516	Capped	513774	8299358	CLARKES BORE	10/21/94	55.5	55x146	49.5	4.0		
29517	Observation bore	516061	8303474		10/13/94	42.8	14x104	24.8		9	13.0-14.0
29518	Observation bore	518190	8301938		10/13/94	24.8	24.5x104		2.0		18.5-24.5
29519	Observation bore	514107	8305018		10/13/94	24.4	24.4x104		3.0		18.4-24.4
29650	Abandoned	514522	8311014		10/14/94	18.8					
29651	Abandoned	517258	8306506		10/14/94	24.8					
29652	Abandoned	517982	8307086		10/15/94	24.8				6.5	
29653	Observation bore	513877	8301296		10/15/94	18.8	13.5x104			11.5	7.5-13.5
29665	Observation bore	512718	8302294		10/28/94	24.6	19.3x104	15.3	2.0	10	15.3-19.3
29666	Observation bore	517982	8307106		10/29/94	17.7	17.7x104	13.7	0.5	6.8	13.7-17.7
29930	Capped	534605	8311516			22.1				dry	
29931	Capped	526157	8306526			78.2				2.4	
29932	Capped	526370	8313318			25				11.2	
29933	Capped	533230	8319249			32.6				5.7	
29934	Equipped	542609	8322961		1982?						
29935	Equipped	547576	8326556	HOMESTEAD BORE							
29936	Capped	536435	8314800			24.5				19.2	
29937	Capped	546709	8328284			15				2.6	
29938	Abandoned	546157	8327010			11.4				1.9	

APPENDIX 2

CHEMICAL ANALYSES OF GROUNDWATERS

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

APPENDIX 2 CHEMICAL ANALYSES OF GROUNDWATERS LEGUNE STATION

BORE RN	BORE NAME	DATE	CONDUCTIVITY	T.D.S.	pH	SODIUM	POTASSIUM	CALCIUM	MAGNESIUM	CHLORIDE	SULPHATE	BICARBONATE	NITRATE	FLUORIDE	IRON	SILICA	ALKALINITY	HARDNESS
			uS/Cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
4118		1/12/63	5280		8.7					2700							480	170
4118		1/12/63	62400		6.9					46000							200	15000
5021	FLAPPER HILL BORE	22/9/65	39700		7.6	8150	240	400		15984	1600	193			0.4		316	4800
5036		23/6/93	1220	657	7.4	144	22	54	29	247	22	238		3.3	0.3		195	254
5043		3/8/73	1090	630	7.5	115	12	50	53	86	30	573		0.8	<0.1		470	342
5043		2/8/90	1170	660	7.2	118	12	52	58	105	56	574		0.5	0.7		471	368
5043		13/8/94	1200	669	7.5	127	12	59	55	118	2	578		0.5	<0.1	34	474	374
5044		1/10/65	37900	31006	7.2	8320	276	104	2780	15165	29	1217			1.4		1996	3040
5133		22/9/65	6000		7.4	630	14	350	336	1941	140	138		0.2	0.6		226	2275
5135		28/10/65	4380	2787	7.1	370	24	620	36	1595	93	165			2.6		270	1700
5147	NELSONS POINT BORE	4/8/73	1820	1020	5.1	277	8	20	36	542	42	3		0.2	0.6		2	198
5147	NELSONS POINT BORE	30/5/90	8230	4650	6.6	1270	45	94	180	2600	250	27		0.1	0.1		22	973
5147	NELSONS POINT BORE	14/8/94	10560	6390	6.0	1790	47	160	226	3590	385	23	7	<.1	0.2	12	19	1340
5180		21/10/65	1000	1168	7.5	233	14.2	40	48	425	190	223			1.3		366	302
5180		21/12/65	4140		7.2			184	144	1092		195			0.9		319	1060
5180		4/8/73	3790	2690	4.6	248	14	232	144	1219	<2	<1		0.2	4.4			1170
5181		20/4/68	2050		7.1													
5181		3/8/76	460	250	7.3	60	8	12	18	32	15	232		0.2			190	104
5182		20/10/65	2140	1463	8.8	400	35	16	3	231	50	477					966	52
5313		20/6/66	2016	1667	6.4	250	8	70	85	608	75	56			4.2		92	530
5313		30/5/90	2720	1575	7.5	278	11	128	72	740	63	214		0.1	<0.1		176	615
5484		14/7/66	2100	2252	7.0	158	14	148	154	778	40	110			0.3		181	1010
5520		19/8/66	1146	719	5.8	145	7	6	37	336	15	4			3.2		6	170
5520		31/10/72	128		5.7							9					7	
5520		3/8/73	290	170	4.8	35	1	5	7	78	3	4		<0.1	0.2		3	42
5520		30/5/90	865	440	5.5	115	2	6	21	211	27	4		<0.1	1.8		3	101
5520		2/6/90	900	470	6.6	128	2	8	22	245	29	14		<0.1	1.7		12	110
5520		11/8/94	502	299	7.7	12	7	59	28	18	25	282	<1	0.2	3.1	24	231	263
5520		13/8/94	910	479	5.2	134	3	6	20	248	20	3	14	<.1	0.1	15	2	97
5521		3/8/73	1130	560	6.1	150	8	15	29	347	8	9		0.1	0.9		7	157
5542		4/8/73	200	130	6.4	24	13	2	3	44	2	29		<0.1	0.1		24	17
5542		1/6/90	265	170	6.6	23	17	5	7	47	10	50		0.1	<0.1		41	42
5599		19/12/66	140	288	6.4	17	2	5	6	18		15		0.5	3.1		24	36
5599		2/8/73	29	36	6.3	3	1	2	<1	8	<2	9		<0.1	0.1		7	5
5609		2/8/73	2710	2060	6.0	340	24	122	62	936	25	12		0.4	18.0		9	559
6669		10/8/73	810	520	7.4	101	6	32	27	120	53	239		0.3	0.1		196	191
7859		13/8/73			7.1										48.0			
7860		13/8/73			6.9										42.0			
7861		13/8/73			6.2										60.0			
7862		13/8/73			7.6										13.0			
23871		19/11/85	90	65	6.6	6	4	2	6	8	9	30		0.1			25	30
23872		20/11/85	110	70	5.4	15	3	1	1	28	4	3		0.1	4.9		3	7
23872		20/11/85	100	55	5.2	13	2	1	1	22	3	2		0.1	3.6		2	7
23872		20/11/85	90	55	4.8	11	2	1	1	22	2	1		0.1	2.0		1	7
23872		20/11/85	70	50	5.1	8	1	1	1	16	2	1		<0.1	2.5		1	7
23872		25/8/86	75	45	4.7	8	1	1	1	16	2	<1		<0.1	0.3		<1	7
23872		10/11/94	43	32	5.3	4	1	1	1	7	1	7	1	<.1	2.7	11	6	7
23873		21/11/85	70	45	5.8	9	2	1	1	12	3	6		<0.1			5	7
23873		21/11/85	85	55	6.3	8	1	4	2	14	2	18		<0.1	3.2		15	18
23873		14/8/94	66	51	5.7	10	1	<1	1	15	1	10	1	<.1	3.7	14	8	4
25201	LONG GRASS BORE	28/7/88	5430		7.5					1536		322					264	1350
25201	LONG GRASS BORE	15/8/94	5620	3620	7.8	657	20	275	183	1750	286	305	<1	0.2	2.0	51	250	1440
25201	LONG GRASS BORE	15/8/94	5620	3620	7.8	657	20	275	183	1750	286	305	<1	0.2	2.0	51	250	1440
25201	LONG GRASS BORE	20/10/94	5030	3088	7.0	595	18	232	164	1400	250	361	<1	0.2	0.4	59	296	1255
25202	BUNDABURG BORE	1/8/88	2560		7.5					662		230					189	615
25202	BUNDABURG BORE	14/8/94	2600	1630	7.7	273	10	163	66	690	58	271	<1	0.1	2.6	23	222	679
27012		1/9/90	500	375	7.9	47	2	29	23	17	12	300		0.2			246	167
27014		1/7/90	20600	12830	8.0	4120	120	86	280	6600	1049	736		1.1			604	1363
27015	OSMANS BORE	19/7/90	215	150	6.9	25	16	2	5	44	7	32		0.1	7.0		26	26

APPENDIX 2 CHEMICAL ANALYSES OF GROUNDWATERS LEGUNE STATION

BORE RN	BORE NAME	DATE	CONDUCTIVITY	T.D.S.	pH	SODIUM	POTASSIUM	CALCIUM	MAGNESIUM	CHLORIDE	SULPHATE	BICARBONATE	NITRATE	FLUORIDE	IRON	SILICA	ALKALINITY	HARDNESS
			uS/Cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
27015	OSMANS BORE	14/8/94	210	138	6.1	24	13	2	4	40	8	37	<1	<.1	3.1	25	30	21
27015	OSMANS BORE	18/10/94	204	140	5.9	24	13	2	4	11		35	<1	<.1	0.1	27	29	21
27016	STEELS BORE	1/7/90	1385	765	6.8	190	7	20	36	416	20	12		0.1			10	198
27016	STEELS BORE	13/8/94	1830	1082	5.6	253	9	31	46	550	38	9	<1	<.1	3.4	19	7	267
27016	STEELS BORE	11/10/94	1610	974	5.5	208	8	26	42	475	29	11	<1	<.1	0.5	20	9	238
27017	SWEETWATER BORE	1/7/90	120	90	6.5	13	1	2	5	23	2	8		<0.1	3.0		7	26
27020	RAINBOW BORE	1/7/90	85	90	5.3	13	1	<1	1	23	2	2		0.1	5.8		2	4
27022	LINDENS BORE	18/7/90	30	30	5.7	6	1	<1	1	7	1	4		<0.1	3.8		3	4
27022	LINDENS BORE	14/8/94	33	44	5.9	5	<1	<1	<1	6	<1	5	6	<.1	0.7	13	4	<1
27128		1/7/90	110	85	4.2	11	<1	1	1	25	2	<1		0.2	6.0		<1	7
27129	BOTTLE TREE BORE	17/7/90	1145	645	8.1	126	12	51	55	102	31	567		0.6	0.8		465	354
27129	BOTTLE TREE BORE	12/10/94	1024	604	7.3	104	14	62	49	89	30	512	3	0.4	1.0	34	420	332
27130		1/7/90	33500	21900	3.4	6250	220	405	850	12870	1302	<1		<0.1	11.6		<1	4498
27802	BEVANS BORE	14/7/91	115	100	6.1	17	4	2	2	33	3	8		<0.1	0.3		7	13
27802	BEVANS BORE	15/8/94	273	164	5.8	37	4	3	5	72	6	12	<1	<1	4.0	25	10	28
27802		2/11/94	180	129	5.5	25	3	2	4	46	5	8	1	<.1	0.2	27	7	21
27803	ARCHIES BORE	17/7/91	105	70	4.1	9	1	2	1	14	11	<1		<0.1			<1	9
27803	ARCHIES BORE	14/8/94	62	60	4.6	7	1	<1	1	13	2	1	<1	<.1	5.2	18	<1	4
27803	ARCHIES BORE	14/10/94	64	78	5.0	8	<1	<1	1	16	3	4	1	0.1	0.2	23	3	4
27804		15/7/91	14100	9290	7.0	1322	123	1114	369	5000	241	38		0.3			31	4381
27805		15/7/91	18290	12307	8.0	3666	130	200	462	5247	2382	608		0.7			498	2393
28622	SNOWS BORE	15/8/94	58	51	5.8	9	1	1	1	10	3	11	<1	<.1	0.7	13	9	7
28622	SNOWS BORE	4/11/94	75	57	5.6	10	2	1	1	14	7	9	1	<.1	0.4	16	7	7
29516		20/10/94	84	86	5.8	7	9	1	1	13	3	22	<1	<.1	0.4	40	18	7
29516	CLARKE'S BORE	20/10/94	84	86	5.8	7	9	1	1	13	3	22	<1	<.1	0.4	40	18	7
29517		13/10/94	19300	13200	7.3	3630	25	343	465	6400	1370	536	2	0.3		65	440	2770
29518		13/10/94	21400	15700	4.0	3320	107	851	805	7400	2030	<1	1	0.1		69	<1	5440
29519		13/10/94	20900	13600	7.5	3910	67	372	525	7200	1000	274	1	0.1		38	225	3090
29656		18/10/94	24400	19100	7.3	4870	15	705	853	6700	5820	480	2	0.1		48	394	5270
29662		26/10/94	120	167	5.9	16	4	3	5	14	22	14	<1	0.3		24	11	28
29665		25/10/94	1520	896	7.9	193	5	62	56	245	113	410	<1	0.5		30	336	385
29666		29/10/94	22000	14500	7.2	3350	37	826	788	7700	1590	303	1	0.2		58	249	5300
29730	RICHARDS BORE	18/11/94	560	314	7.7	55	9	35	23	32	20	323	<1	0.1	1.9	1.7	265	182

APPENDIX 3

WATER QUALITY REQUIREMENTS FOR STOCK AND DOMESTIC WATER

1. WATER QUALITY STANDARDS FOR STOCK USE

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

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.

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

APPENDIX 4

PUMPING TEST RESULTS

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

RN	BORE NAME	PUMP RATE (L/s)	PUMP SETTING (m)	BORE DIAMETER (mm)	SWL (m)
25201	Long Grass	3	22	152	10.4
27015	Osmans	2	25	142	11
27016	Steels	2	25	142	12.1
27129	Bottle Tree	0.2	55	142	16.3
27802	Bevans	1.5	25	142	10.2
27803	Archies	1.5	24	142	11.4
28622	Snows	3	20	142	7.8
29516	Clarkes	3	25	142	14

PUMP RATE -The recommended pump rate in litres per second

PUMP SETTING -The recommended depth below ground level at which the pump 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 immediatly prior to the test

APPENDIX 5

DAMS AND WATERHOLES ON LEGUNE

1.Stud Paddock Dam:
This is a small shallow excavated tank which has some of the characteristics of a drainage-line type. About 400 head of cattle drink from it but it goes dry by August. With 300 head of cattle, the demand being from January to July, the reliability of the tank is 80%. The tank was constructed last year. Further excavation is recommended, however subsoil investigation is required to make sure the soil is suitable. The excavation should stop well above the rock layer.

2. Snow's Dam:
This is an onstream excavated tank similar to a drainage-line type, with a natural inlet channel. About 250 head of cattle could be watered from it over a year with a reliability of 90%. With the non uniform demand as practised, the demand being from January to August, the dam can cater for 650 head of cattle with a reliability of 87%. It serves 700 head of cattle at present and usually dries up by September.

3. Billabong Hole:
This is an excavated waterhole which usually dries by June. It is shallow, and can cater for 100 head of cattle from January to May with 90% reliability. Deepening is recommended, however subsoil investigation is required to make sure the soil is suitable.

4. Hill Paddock Dam:
This is an onstream excavated tank which dries by September. Built in 1993, the banks were washed out in February 1994 and it has now been reconstructed. It can cater for 200 head of cattle from January to August with 90% reliability. The spillway should be widened and strengthened by laying rubble packing. Any deepening of the dam would depend on the results of the sub soil investigations.

5.No. 2 Dam:
This is a small and shallow waterhole excavated in 1994. It dries up in August and is similar to a drainage-line tank. From January to May it can supply water to 150 head of cattle with a reliability of 90%.

6. Baker's Dam:
This is a gully dam with a six metre high wall. Constructed in 1994, it has two spillways near the abutments on either side. It was built for irrigation and stock watering. During the 94/95 wet it spilled and the highest water level recorded was 75 millimetres below the crest of the dam. Both the spills were eroded and rubble packing was done to stop further erosion. Over a year, 800 head of cattle can be watered with 90% reliability. The manager intends to water 200 head and use the balance for irrigation. At present the irrigation demand is not known. The width of the spills need to be increased to more than 17 metres each to accomodate 1 in 5 year flood, so that the flood does not overtop the bund.

The bund was constructed using a bulldozer, and so compaction may prove to be inadequate. The spillways are also inadequate. Since the upstream section of the bund is not protected, waves may accelerate erosion. Rubble packing of the spillways and slopes of the main bund are recommended.

7. Red Rock Turkey Nest Borrow Pits:
There are four rectangular borrow pits around the turkey nest which fill with water during the Wet but go dry by June. Seven hundred head of cattle can be watered from this source from January to May with 90% reliability. As January and February are wet months, the pits can cater for 850 head of cattle with 90% reliability. It is recommended that these pits be further excavated so that they can store more water. Subsoil investigations are recommended before any excavation proceeds .

8. Weaner Dam:
This is a typical drainage-line tank. It is small and shallow and dries up by September. Two hundred head of cattle can be supplied from January to August with 90% reliability. As January and February are wet months the dam can cater for 250 head of cattle with 90% reliability for a six month daily supply. It is recommended that the dam be expanded and deepened so that it can supply till the end of dry. Deepening will be subject to the presence of suitable subsoil.

9. Corner Dam:
This is a drainage-line tank. The bund slopes are steep and weak and it is likely that insufficient compaction was done. It can cater for 200 head of cattle from January to July with 90% reliability. However with the usual wet months of January and February, it can cater for 250 head of cattle. The dam goes dry by August so it is recommended that it be expanded and deepened. Any further excavation would depend on the results of the subsoil investigations.

10. Barrummundi and Turtle Point Borrow Pits
There are three rectangular borrow pits around each of these turkey nests which fill with water during the Wet but go dry by June. Three hundred and fifty head of cattle can be watered from each of these from January to May with 90% reliability. As January and February are wet months the pits can cater for 400 head of cattle with 90% reliability. When the pits run dry in June the turkey nests are supplied by bores. It is recommended that these pits be further excavated so that they can store more water. Subsoil investigations are recommended before any excavation proceeds .

11. Alligator Waterhole
This waterhole is deep and has never been recorded as going dry. It can supply water to 800 head of cattle throughout the year with 90% reliability. In reality it can serve up to 900 head of cattle with 90% reliability when the demand is from March to December. At present about 1100 head of cattle are being watered there.

APPENDIX 6

SITE INVESTIGATIONS

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

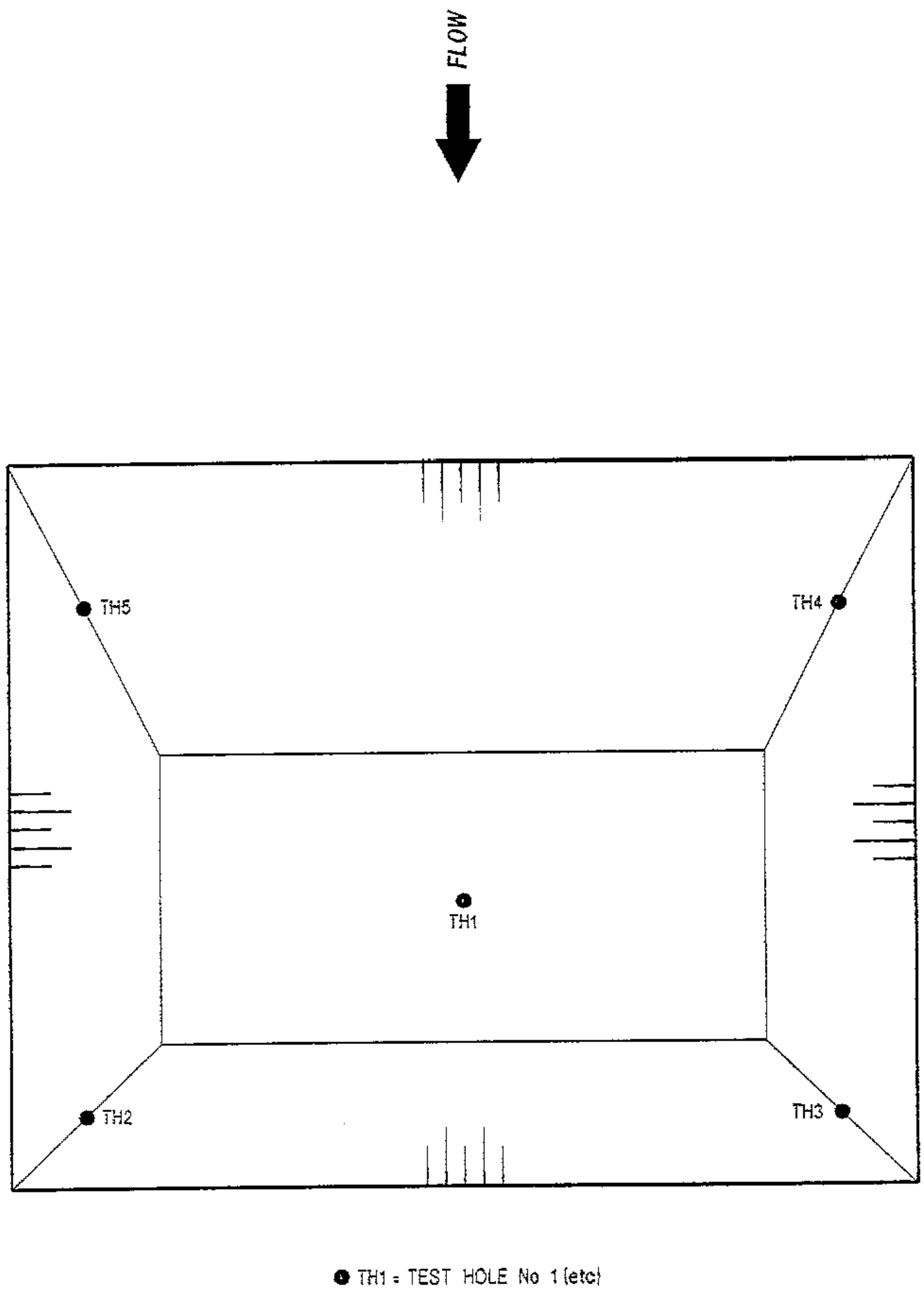
If an onstream tank is proposed then spillway conditions will also require investigation. If it is too sandy it will erode and wash away or if it is in rock, excavation could be very expensive.

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 6). 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
- silting 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.



TEST HOLE PLAN FOR
AN EXCAVATED TANK

Fig 6

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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 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 Conservation Commission of the Northern Territory 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

APPENDIX 7

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 be 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 it's storage capacity. The bund should have a minimum berm width of 5 metres (Figure 4). 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 of 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, eg. using a tilted grader blade, to direct an increased volume of sheet flow towards the tank.

2. 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:

NUMBER OF CATTLE	INNER DIAMETER AT BASE (metres)	INNER DIAMETER AT TOP (metres)	HEIGHT (metres)
200	6	13	1.1
500	8	16	1.5

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

3. 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.

APPENDIX 8

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.

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.

PLATE 1: Snows dam an onstream tank

PLATE 2: Weaner dam a drainage-line tank, looking east towards the Victoria River

PLATE 3: Bakers dam a gully dam

PLATE 4: Red Rock turkey nest and borrow pits, looking north