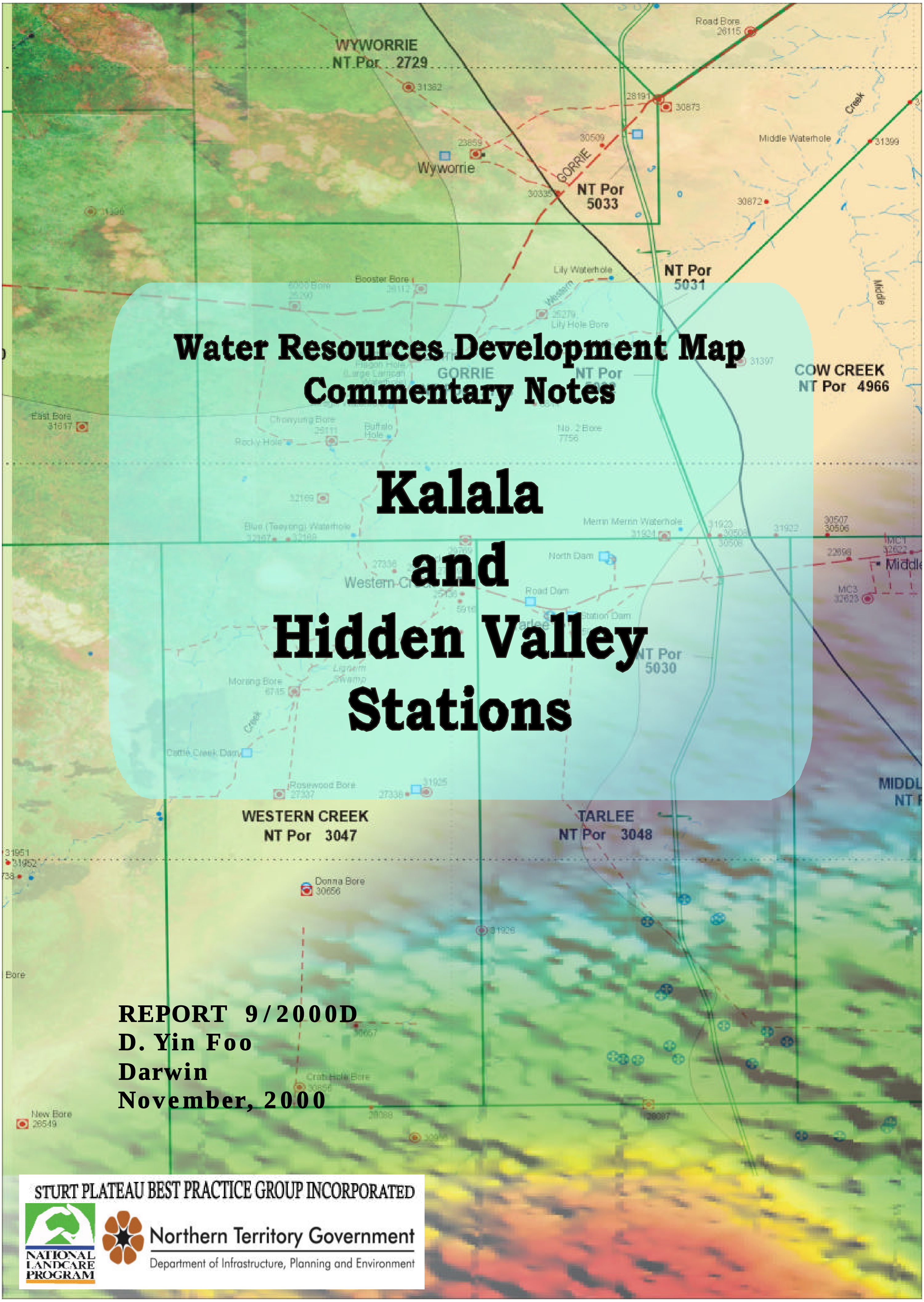

Water Resources Development Map Commentary Notes

Kalala and Hidden Valley Stations

REPORT 9/2000D

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Darwin
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STURT PLATEAU BEST PRACTICE GROUP INCORPORATED
NATIONAL LANDCARE PROGRAM
Northern Territory Government
Department of Infrastructure, Planning and Environment

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LIST OF ABBREVIATIONS

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

LIST OF CONVERSIONS

1 mm (millimetre)	=	0.04 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

PLATES

SUMMARY

This Water Resources Development map is designed as a guide in determining the most appropriate type of water supply for an area.

Groundwater throughout the Sturt Plateau is mainly exploited from aquifers developed in the fractures and cavities of a limestone formation. The limestone is layered between surface sediments up to 60m thick and a basalt basement. The basalt is non-water bearing, except where fracturing is present. The thickness of limestone, and therefore the groundwater availability, varies with the undulations and features of the basement. However, within the region covered by this map, the basement is usually at a depth such that it has no influence. As a consequence, the groundwater potential is largely considered as excellent.

Surface water development options within the map region are also generally good. However, experience with dams elsewhere in the Top End has shown that hazards posed by the wet season need to be considered. An effective dam must resist potential flood damage, have viable capacity and harvest adequate sheet flow from the catchment. Tank and dam construction on the Sturt Plateau is limited by difficulties associated with flat topography and low runoff potential. However, there is usually sufficient clay in the soil for viable dam construction. Evaporation is high and deeper dams with adequate storage to persist through the dry season may not always be an option. In such instances, shallower tanks or dams are still viable and will permit a greater area of pasture to be used for at least the early part of the dry season.

1.0 INTRODUCTION

This map and accompanying notes represent one in a series of four covering the Sturt Plateau region. The intention was to provide station managers with a map tool containing up to date information on water resources. In conjunction with other natural resources maps, planning and management at property scale will be feasible.

The Sturt Plateau Best Practice Group (SPBPG) provided the initiative for this project. The Northern Territory Government and the National Landcare Program took carriage of, and jointly funded this project. The water resources in the Sturt Plateau region, comprising 23 properties and land trust areas, was studied between May 1997 and June 2000.

The Sturt Plateau region covers approximately 30000 km^2 and defines an area which extends between Mataranka in the north and Dunmarra in the south. The eastern boundary is featured by an upland area parallelling the Stuart Highway. It is bounded to the west by the Buntine Highway. Road access is good throughout the region. During the wet season, the main roads are generally accessible by light vehicles, although many station tracks may be impassable.

Plate 1 - Looking west along Buchanan Highway from turnoff to Hidden Valley Station

The availability of stock water is a major influence on stock management. Nearly all of the annual rainfall, which averages about 800mm, occurs in the short hot monsoonal wet season between December and March. Little rainfall is experienced during the remainder of the year. Recharge to groundwater systems occurs at this time. Evaporation rates of water bodies such as dams or waterholes are between 5 and 11 millimetres per day (average about 8 mm per day or 2.8 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 29 degrees in June to 37 degrees in December. The corresponding average monthly minima are 13 and 24 degrees. Climatic data for Larrimah, at the centre of the Sturt Plateau, are presented in Table 1.

Plate 2 - 'D' bore and ground tanks at Kalala

In this map sector of the Sturt Plateau, bores currently supply the vast majority of stock water needs with the remainder coming from waterholes. Where bores are used, steel tanks and turkey nests are popular as temporary storages. During the wet and the early dry season, most of the surface water that is accessible is used, but as the dry season progresses, these sources usually become depleted. A few of the deeper waterholes are known to persist throughout the year.

TABLE 1

CLIMATIC AVERAGES for LARRIMAH

	Rainfall (mm)	Rain Days	Daily Min. Temp (^{0}C)	Daily Max. Temp (^{0}C)	Daily Evap. (mm)
January	201	15	24.0	35.5	10.4
February	191	15	23.6	34.3	7.9
March	154	11	22.5	33.7	7.5
April	33	3	19.6	33.8	8.6
May	14	1	16.2	31.4	6.1
June	5	1	12.8	29.2	5.0
July	4	1	12.0	29.0	6.0
August	0	0	14.7	32.1	7.2
September	5	1	17.9	34.7	6.9
October	27	3	21.6	37.0	8.6
November	65	7	24.1	37.7	11.4
December	113	10	24.3	36.9	8.3
Total	812	67			

2.0 WATER SUPPLY DEVELOPMENT

The accompanying Water Resources Development Map gives a broad view of the most likely and suitable development option for stock watering. The map classifications are based on a combination of information on groundwater occurrence, soil types and topography. Local conditions, such as soil types can vary considerably, so the maps should not be taken as a definitive guide to cover every situation. Detailed on-ground investigations are recommended when considering specific developments.

For an explanation of the colour codes on the main map, refer to the legend entitled "Water Resources Development Options". Four categories of "preferred options" have been mapped:

OPTION 1 - Where natural waterholes exist, piping from these features is the most appropriate development option. Man made surface water developments are not suitable and the area is not likely to produce adequate stock supplies from bores.

OPTION 2 - Within this area, surface water development, particularly dams or excavated tank constructions, are viable and the area is not likely to produce adequate stock supplies from bores.

OPTION 3 - Groundwater is a viable option within this area. Surface water developments are not suitable.

OPTION 4 - Water supply development is viable using either groundwater or surface water sources.

Some of the main features of the development map are:

- groundwater availability is good for the majority of the map.
- towards the southern part of the map, groundwater prospects are high with deep bores and correspondingly deep water tables (>100m).
- most areas are suitable for surface water development. The construction of drainage-line excavated tanks are preferred due to the flat nature of the landscape.

3.0 GROUNDWATER

Groundwater prospects across the area have been assessed using information on geology, ground and airborne geophysical surveys and from existing boreholes. Assessment of this data has enabled a more detailed side map entitled the Groundwater Resources Map, to be produced. 'The Thickness of Limestone Below the Water Table' and 'The Depth to Water Table' side maps should be used as guides to minimum bore depths and indicative pumping depths and are applicable to areas within the limestone basin.

Technical information on bores in the area is held on the Natural Resources Division's files and is available on request. Chemical analyses of groundwaters from all bores and guideline limits for common uses are listed in Appendix 2 and Appendix 3 respectively.

Plate 3 - Karstic weathering

Within the study area, the vast majority of bores exploit an aquifer within an extensive limestone formation. These systems are termed karstic - a term which describes a landscape resulting from dissolution and weathering of limestone, and usually noted for cavern development. An aquifer thus formed comprises a myriad of interconnected cavities and fractures developed within the horizon of the host rock, which allows movement of groundwater through it. Successful bores intersect submerged cavities, voids and fractures in the formation.

Three categories, representing 'expected or likely bore yields', ranging from less than 0.5 L/s (poor success rate) to more than 5 L/s (high success rate), are referred on the Groundwater Resources side map. For stock watering, bores yielding above 0.5L/s are generally regarded as successful.

Consider a typical case of a paddock holding 1000 head of cattle (each consuming 50 litres per day). Adequate stock watering is represented by a pumping regime yielding a minimum of 0.5 L/s continuously. This equates to a bore yielding 1 L/s to run two days out of four. A bore yielding more than 2 L/s to top up storages intermittently would provide a good safe margin.

The expected yield is based on knowledge of the type of aquifer, and in some cases, the submergence characteristics. For example, consider a limestone aquifer. Where the aquifer submergence is greater than 20m, a bore intersecting a cavity or fractured rock will likely yield in excess of 5L/s.

Where the submergence is less than 20m, but more than 5m, a yield of between 0.5 and 5L/s may be expected. In an area where the submergence is less than 5m, the likelihood of intersecting a cavity or fracturing in the formation within this interval, is low. Therefore it is considered as a poor prospect because there is a high risk of failure.

Water quality from all aquifers across this region of the Sturt Plateau is suitable for stock. Appendix 2 tabulates the available water analyses from bores in the area.

The three zones depicted on the groundwater map are now described:

3.1 Areas of Poor Likelihood of Success

There is only a small area of this map sheet within this category and may be considered inconsequential. However, such an area emanates from an expanse of the Sturt Plateau further north where the water table is approximately coincident with the top of the basalt basement. Groundwater occurrences in this particular environment depend on intersecting fractures in the basalt. There is difficulty in locating fractures as they are generally masked by a cover of sediments up to 50m thick. Bores intersecting the weathered surface of the basalt, in some instances, may yield about 0.3 L/s. Under this scenario, the prospect for locating stock supplies is considered low.

Aquifers developed in the basalt are usually isolated and independent and hence water qualities from different bores vary considerably. However, within this map area, the water quality would be satisfactory for stock.

Groundwater options improve away from this area, and therefore it is recommended that developments involving groundwater be avoided.

3.2 Areas of Moderate Likelihood of Success

The aquifer within this zone is part of the regional limestone basin which underlies the majority of this map (refer cross sections on the map). Bore yields can be expected to range from 0.5 L/s to more than 5 L/s. Variation in success and yield from bores within this category can be attributed to at least four factors.

Firstly, natural variations in the properties of the rock and in the development of dissolution features of the limestone leads to variations in groundwater yields. Also, where cavities or fractures exist, the need to be intersected by a borehole – usually 200mm in diameter before a successful yield is obtained.

Secondly, bore yields also depend on the aquifer's submergence characteristics. This term describes the location of the aquifer in relation to the water table. Submergence will vary with the undulations of the ground surface and by virtue of the random nature of aquifer occurrence within the limestone.

Bore construction, and the drillers' skill may also influence bore yields. Drilling in the limestone environment of the Sturt Plateau is difficult. Cavities usually exist above the water table as well as below it, and these can determine how drilling progresses and also the outcome of the hole. The driller's assessment of the strata, the depth to the aquifer and the possible yield from the bore depends on uphole returns of drilled cuttings and intersected water. Where cavities exist, and the returns are 'lost' into them, this data becomes ambiguous. The bore is eventually constructed based on the drillers' perception of the available data and sometimes his experience. Although a potential for error is recognised here, in most cases, bores producing at stock supply rates have a good tolerance level for errors in judgement, and many have been successfully constructed.

Another significant reason for the variability in bore success across the Sturt Plateau is the presence of a structural feature within the basalt basement. The feature is a system of parallel ridges and troughs trending north-west / south-east across the central Sturt Plateau. In the extreme cases, the higher ridges intersect or approach the water table. This affects groundwater conditions and creates corridors that are non-prospective for groundwater. In this map area, these ridges only feature along the northern margin of Hidden Valley Station.

The use of airborne geophysics has enabled these features to be mapped (Reference 1). Where they are prominent, bore site selection can be critical. It is important that the troughs be targeted to intersect an adequate thickness of limestone and optimise aquifer submergence. A map showing these basement features is considered an essential tool in bore site selection within the affected areas, and is available from the Natural Resources Division upon request.

The limestone aquifer within the map area is distinguished by different water qualities between Hidden Valley and north of Daly Waters. This is possibly due to the influence of local recharge conditions. However, in all cases, the water quality is considered to be suitable for stock. A measure of salinity, known as the total dissolved solids (TDS), is considered the primary indicator of water quality. The desirable limit for human consumption is 500mg/L, although up to 1500mg/L is acceptable. Cattle will tolerate a TDS of up to 10000mg/L (refer Appendix 3).

Plate 4 - Drilling on the Sturt Plateau.

Typical TDS values in the Hidden Valley area are less than 500mg/L while north of Daly Waters, TDS levels are over 1000mg/L. The higher salinities in the Daly Waters area result from a combination of carbonates, and sulphate and sodium chloride salts.

The waters are hard to very hard (total hardness over 250 mg/L) and scale forming. Measures can be taken to minimise the occurrence of scale development on elements of the reticulation. These include control of thermal variation of the reticulated water and limiting the aeration of the water.

3.3 Areas of High Likelihood of Success

Mapping of these zones is based on areas where aquifer submergence exceeds 20m. Within the map area, this zone covers the majority (refer Groundwater Resources Map). There is a high likelihood of success for stock bores with yields in excess of 5 L/s.

Because the limestone beds 'follow' the basement (basalt) shape, geological faulting in the region as well as the trend of the basement to deepen towards the south, has resulted in increased submergence across much of the map area. (refer Cross-Section A-B). These factors, in conjunction with rising land elevation to the south, has resulted in an increase in depth to the aquifer and an increase in depth to the water table.

It is important to note that although the aquifer in this area may produce high yielding bores, there is currently a low level of information available on which to assess the sustainability of the resource. Issues of resource sustainability, environmental impact and allocation need to be addressed in these areas if large scale water usage (eg. horticulture) is considered.

4.0 SURFACE WATER

Few man made surface water storage constructions exist on the Sturt Plateau. The generally flat topography, low runoff potential of the area and high evaporation rates may make excavated tank and dam construction unattractive as primary water source options. However, regardless of the difficulties that these factors pose, surface water development options do exist for most areas and formal and purposeful design will provide these options. Even if preferred as secondary options, shallow tanks or dams need to be considered and will permit a greater area of pasture to be used for at least the early part of the dry season.

The major river systems that drain this map area are the Sunday Creek and Daly Waters Creek systems which both join Birdum Creek, and the Strangways River in the north-east of Kalala. For the most part, the land is of broad, flat to gently undulating plains and is typical of the Sturt Plateau. Of particular note is the lack of well-defined drainage paths across much of the country. Towards the south-central area of Hidden Valley and south of Daly Waters the country is distinguished as a different catchment type, developing low hills and crests, with shallow ferruginous gravels.

Flow records exist for Daly Waters Creek in the upper Birdum Creek catchment. These records are indicative of the general runoff characteristics over the Sturt Plateau where only a small percentage of rainfall (less than 10%) eventually contributes to sheet flows. Flow only occurs during the wet season after the catchment has been adequately wet or following significant rainfall events. Initial wetting of the catchment may account for up to 40% of the total seasonal rainfall each year. See map side graphs for Daly Waters Creek flow data and indicative regional rainfall figures.

Typically, the drainage systems on the Sturt Plateau deplete to form isolated pools in the rivers, and waterholes on the relict channel (black soil) areas of the flood plain. The majority of these are dry by about August or September.

The region's suitability for surface water development has been assessed by broadly adapting the land systems classifications and supplementing this information with field testing. The Land Systems Classifications (Reference 2), which integrate factors including topography, soil and vegetation types provide an approximation to relative runoff characteristics. Field investigation at a number of localities has allowed assessment of site suitability in terms of depth and clay content and enabled comment on the water retention characteristics of various soils. The results are presented as the Surface Water Resources Map, one of the side maps accompanying the Water Resources Development Map. However, it should be noted that the broad scale of this map is primarily for planning purposes and does not preclude the need for site specific investigations.

4.1 Surface Water Storage Types

By its nature, monsoonal rainfall in the Top End gives rise to discrete, sometimes significant flow events in local drainage systems. Dam construction types, which are sympathetic to this regime but enable effective and adequate harvest of surface water, are limited. As well, the general lack of defined drainage courses on the Sturt Plateau further limit options.

Three types of excavated tanks are suitable for the generally flat to gently sloping plains of this map region. They are on-stream tanks, off-stream tanks, and drainage-line tanks (see Figure 1 below). An on-stream tank is one dug in a well defined stream channel. Off-stream 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 on-stream excavated tank requires a high standard of design and construction and is prone to erosion and silting because of its location in a fast flowing main stream channel. The off-stream design (see Figure 2) reduces these problems by using a man-made channel to divert water from the stream to the tank. This is an improvement on the on-stream design, but has excessive excavation costs because to take advantage of short duration stream flows, the tank level must be below that of the natural stream bed.

The drainage-line tank or hillside storage is constructed in flat to moderately sloping areas where there are no clearly defined incised creeks. This type of construction is considered the most suited to the environment of this area. The tank itself is of the same design as the off-stream one, but without an inlet channel (see Figure 3). Sheet flow on the plains, with its low silt load, may be harvested. Catch drains or wing walls directing flow towards the dam may be used to enhance interception capacity.

Some common problems experienced with excavated tanks include the following:

- inadequate spilltail channels do not direct water away from bunding
- erosion of wing walls
- silting of catch drains

Regular maintenance is required before the wet season to correct these problems.

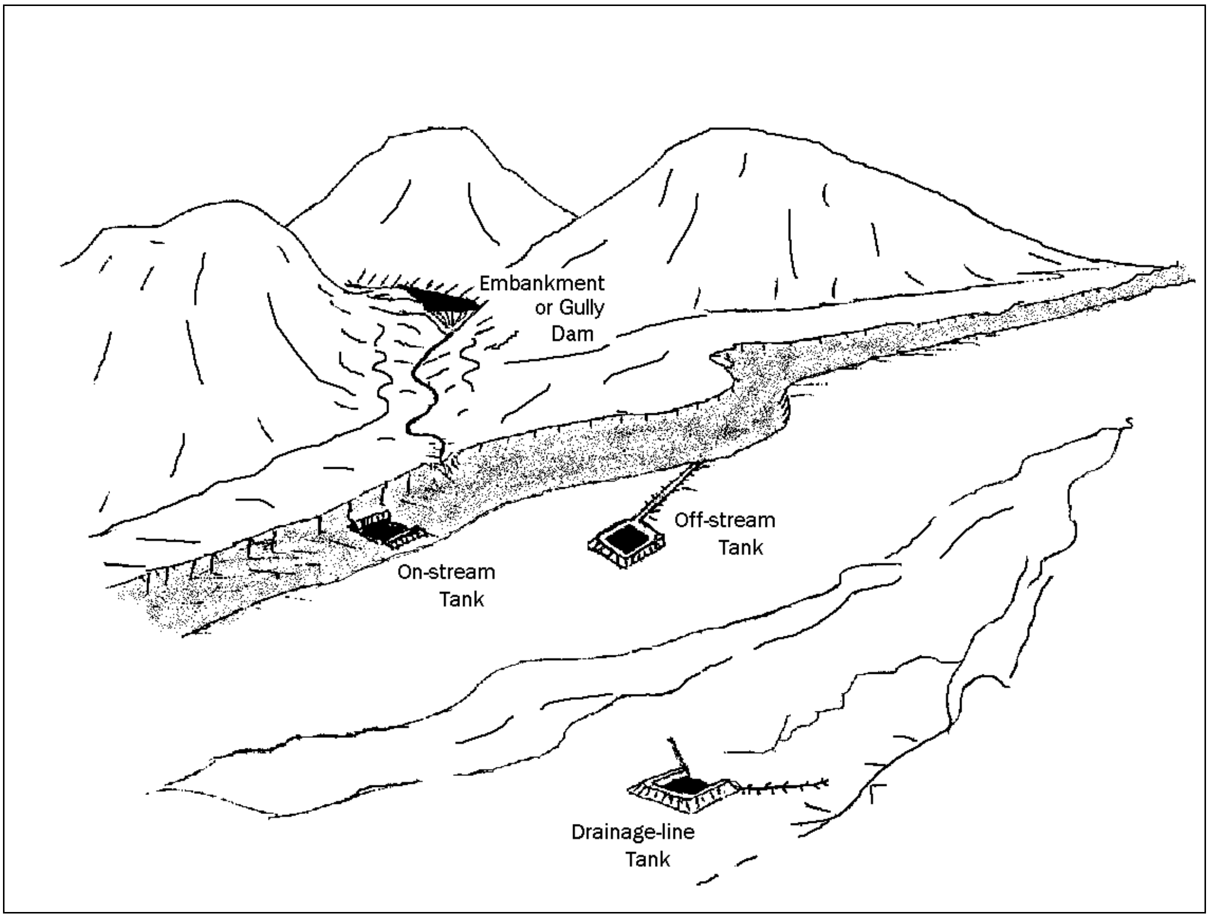

Figure 1 Types of Tanks and Dams

Another type of dam, the gully or embankment dam, is suited for 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 gully dams involves potential high costs in dealing with the foundations and mitigation of flood flows with diversion through an adequate by-wash or spillway. It is recommended that appropriate planning and design be undertaken, particularly for construction on rock foundations.

Within the map region, this type of construction may be suited to the more hilly country to the south-west of Hidden Valley and south of Kalala. However, the feasibility and economic viability of the construction would need to be checked as leakage through the upper soil profile as well as the availability of local construction materials may be limiting factors.

Plate 5 - A drainage line dam at Hidden Valley Station

The "Earth Movers Training Course" booklets 9 and 10 (Reference 3) and "Design and Construction of Small Earth Dams" (Reference 4) are both excellent background guides to dam building and design. However, it is important that the information be considered in conjunction with local knowledge as many of the dam types are only applicable to the less extreme conditions experienced in southern climates.

4.2 Selection of Sites for Excavated Tanks

The availability of runoff and depth of impermeable soil are usually the determining factors in site selection for excavated tank construction. Conditions appear to be favourable across the major part of the map area as it comprises gently undulating plains to low hills. The soil appears to have adequate clay content and sufficient depth.

In areas mapped with cracking clay (black) soils, such as the relict drainage paths in the north of Hidden Valley, the clay may extend to depths of about two metres in most places and will be suitable for excavated tanks. However it should be noted that this is unlikely to be sufficient depth to be economical, and hence underlying soil conditions should also be investigated to confirm viability.

A drainage-line tank is best suited to this country where there is flat or gently sloping ground. Excavation will be minimised where the tank site has some slope, say about 1:100, to allow bunds constructed from excavated material to add to the storage volume of the tank. Drainage-line tanks may also be feasible in areas immediately adjacent to the low hilly country on rippable laterite horizons if there is sufficient depth of clayey soils.

A few areas have been mapped where ferricrete is predominant on the surface. This rock, in its 'in-situ' form is highly permeable and would appear to be non-prospective as a foundation for shallow dam or tank construction. However, Avago and Hidden Valley have conducted informal trials in such areas using small holding dams, and report that success has been achieved over a short period of time, simply by allowing animals to 'work' the soil in the dams. After the soil is 'pugged in', a seal is effected. A number of landholders, through personal communication, report a similar result is commonly noted in sinkholes, where once freely draining 'holes' are 'pugged' when animals are allowed access into them.

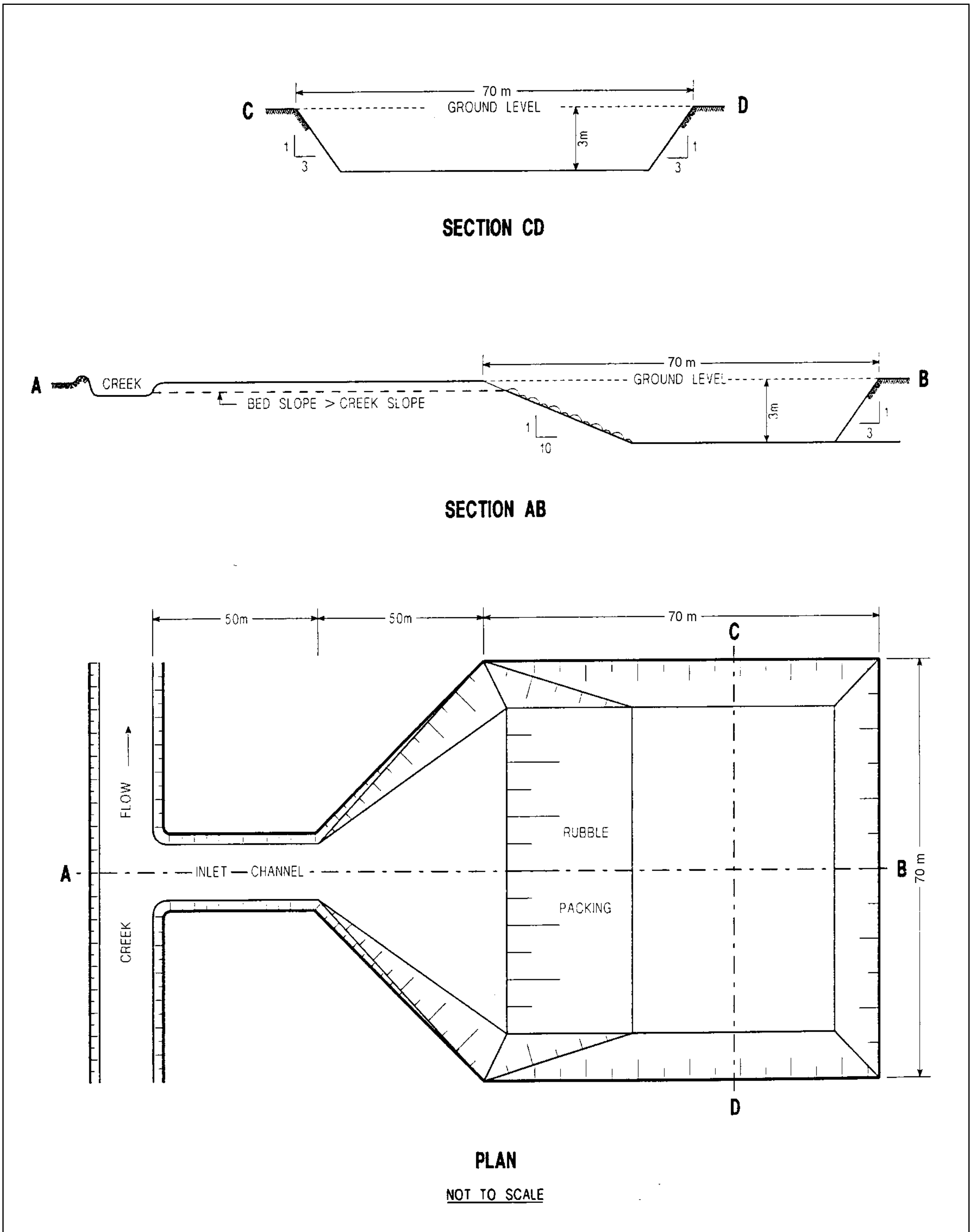

Figure 2 Typical Off-Stream Excavated Tank

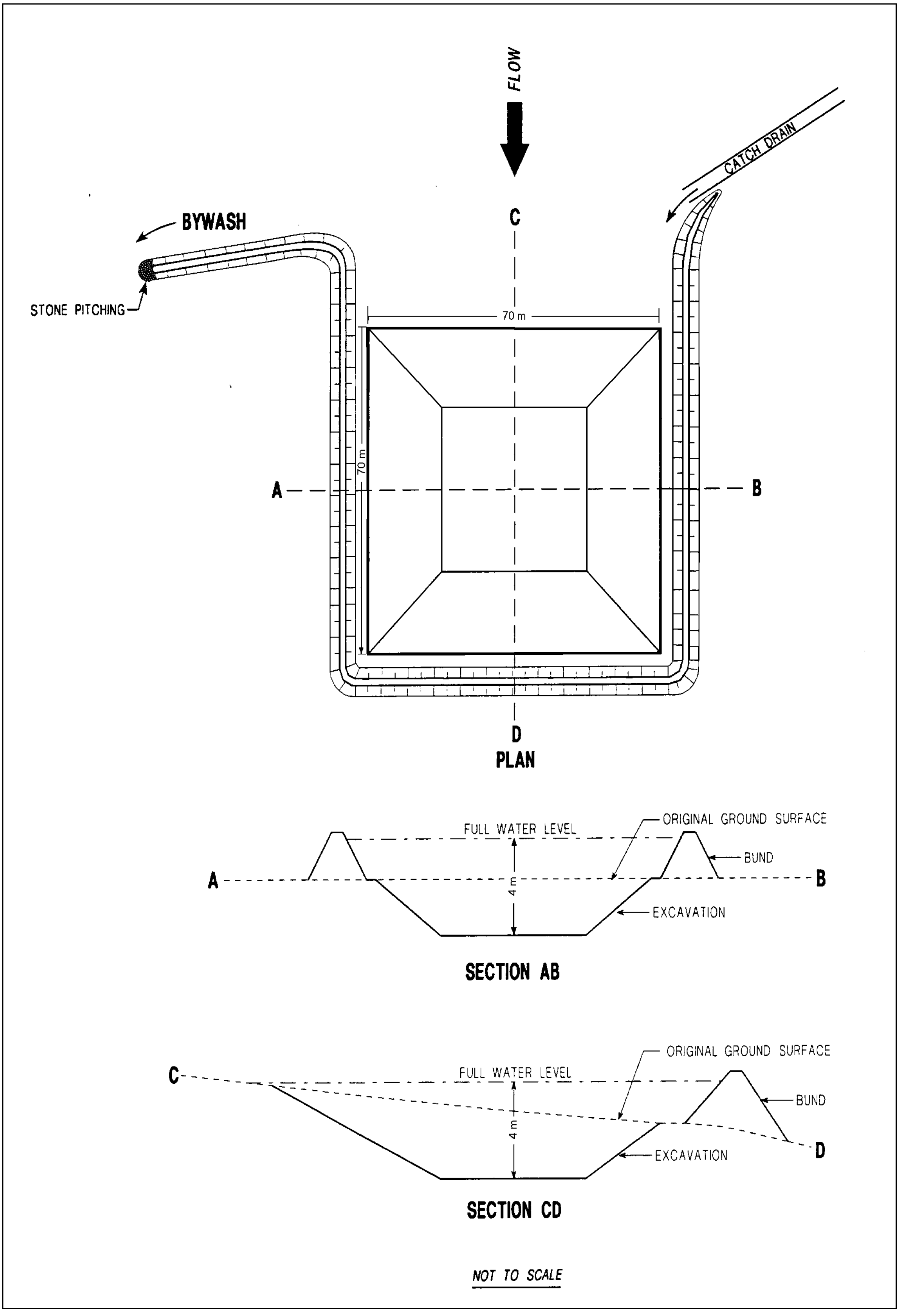

Figure 3 Typical Drainage Line Excavated Tank

Areas mapped with variable soils are minor, but they may also be suitable for excavated tanks. In these areas, there is a likelihood of encountering dispersive or sandy profiles, or high permeability zones and these should be avoided. Remedial work such as installing a clay liner brings added expense but would be necessary.

4.3 Design and Construction of Excavated Tanks

In this section, empirical calculations are used for example purposes only. However, it serves to demonstrate typical dimensions which may be encountered on the Sturt Plateau.

The design dimensions for an excavated tank are determined by the number of stock in the paddock to be watered. This is often governed by the carrying capacity of the country and grazing radius. On the Sturt Plateau, this would be typically between 400 and 800 head. Based on a consumption of 50 litres per head per day, the corresponding water requirement is between 6 ML and 12 ML for the 9 month period from April through to December. With a depth of about 4m, which is the minimum preferred for good reliability and 1:3 batters, the larger tank would measure approximately 70m square at the top.

Following from this example, a storage of 12 ML (if neglecting evaporation and leakage losses) as a drainage-line dam would need a minimum catchment area of about 1 km^2 for the typical environment. This figure assumes an average annual rainfall of 700mm, a runoff threshold of 60% of rainfall and a runoff coefficient of 5%. For tank sizes of larger or smaller storage capacity, the required catchment area would need to be varied correspondingly to capture the required amount of runoff.

The proposed design is indicated in Figure 3 and is relatively simple. Excavated soil can be dumped to waste or used to build a bund on three sides of the tank. Bund and wing walls will increase the storage capacity of a drainage-line tank where there is a moderate slope on the natural ground surface. The excavated volume in this example is large for the proposed design dimensions (approximately 10,000 m^3) so construction costs will be high (usually in the order of $\$1/m^3$). The cost will also be influenced by ground conditions. Tank construction is described in more detail in Appendix 5.

An off-stream tank shown in Figure 2 is similar and with 12ML capacity. However, its ‘filling’ capability is controlled by the elevation of the inlet channel in relation to the creek bed and the nature and frequency of flow in the creek. The hydrology of the creek would therefore need to be examined to enable a viable tank to be designed.

4.4 Waterholes

In the dry season, natural waterholes are found in depressions in streambeds and in the black soil areas of relict floodplains. Most are shallow and become dry a few months after the end of the wet season. The available capacity of such waterholes may be increased by excavation of the base (Appendix 5), but only where clay or a rippable and impermeable rock underlies the site.

Many waterholes exist in the area and appear to be the result of 'plugged' sinkholes. Some are perennial, however, are shallow by the end of the dry season. The storage capacity of well confined waterholes with high banks could be increased by construction of a bund at its downstream end. The bund would need to be designed and constructed to withstand flood flows.

Plate 6 - Malogie Waterhole on Kalala Station

4.5 Piping of Surface Water

Surface water may be piped from borrow pits into turkey nests and this practice is effective as an alternative low cost option where possible. The use of turkey nests is a good option as losses to evaporation can be minimised. 50mm polythene pipe, buried where possible, can be used to pipe water to about 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 (eg. 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 5. 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.

Plate 7 - 'Gunja bore' with ground tank in the background

5.0 RECOMMENDATIONS

- The water resources development map should be used during the conceptual planning stage to determine the type of water supply most appropriate to the development of specific areas on the property. In areas where a number of options are available, economics will normally determine the final development type selected.
- Groundwater is available over much of the region.
- Surface water development options have been indicated to be viable over a large part of the map area.
- 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.

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

5.1 Water Supply Distribution

Over-grazing will severely reduce ground cover and eventually, initiate soil erosion. A major adverse effect is the degradation of pasture quality by allowing non-beneficial 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 for a maximum spacing of twelve kilometres between watering points. Otherwise the water can be piped to steel tanks / 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 4 is an example layout showing the potential increase in the size of the grazing area due to improved water reticulation from a bore or tank.

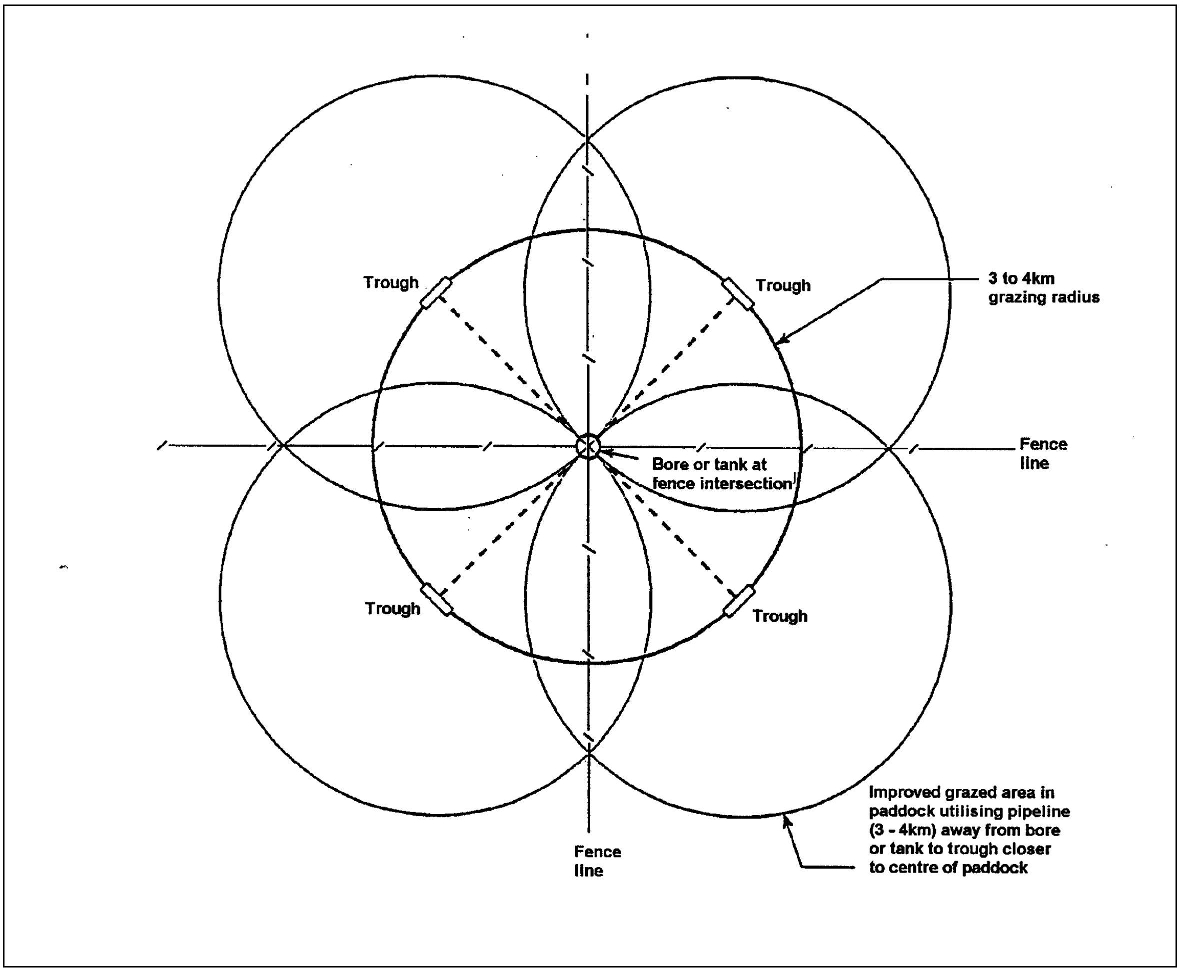

Figure 4 Sketch showing increased size of grazing area due to improved water reticulation from bore or tank

5.2 Groundwater

Within the map area, the prospect for obtaining a groundwater supply in the underlying limestone aquifer is good to high. This is indicated on the 'Groundwater Resources' side map. 'The Depth to Water Table' and 'Thickness of Limestone Below the Water Table' side maps should be used as a guides to minimum bore depths and indicative pumping depths.

Site selection is only critical in the northern margin of Hidden Valley as indicated in the 'Groundwater Resources' side map. A map tool indicating basalt basement features is recommended as an aid to appropriately siting bores in this area and is available from the Natural Resources Division.

Groundwater supplies are readily available elsewhere in the map region. Of particular note are the depths to the water table in the southern parts of the map, primarily the result of the increase in land elevation. Correspondingly, bore depths are greater due to the increase in thickness of sediments overlying the aquifer.

5.3 Surface Water

The 'Surface Water Resources' side map accompanying the main map provides an indication of the potential for dam and excavated tank construction over the area. However, this is based on broad scale mapping and intended for planning purposes only. Field investigations are an essential prerequisite for any construction work and site specific investigations will need to be conducted to ascertain the viability of particular sites.

Drainage-line and off-stream type excavated tanks are recommended for Top End conditions. These construction types are less susceptible to washout during seasonal flooding, and more effective in harvesting the low runoff available from the catchments on the Sturt Plateau.

Generally, the sub-soils are suitable for dam construction. Where clayey soils are shallow or there is underlying shallow rock, small capacity excavated tanks should still be considered. The supply may not be sustained throughout the year, however, a greater spread of grazing will possible for the initial part of the dry season.

6.0 ACKNOWLEDGMENTS

The author would like to thank the managers, families and staff of all stations involved for their time, assistance and fruitful discussions during the study.

The work of Anthony Knapton contributed largely to the outcomes of this project. His assessment and analysis of the geophysical components, particularly airborne magnetics, laid the cornerstone for the current understanding of the basement structure.

Technical advice and guidance from Peter Jolly and Gary Humphreys throughout the survey has been much appreciated.

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7.0 REFERENCES

1. Knapton, A. , “Water Resource Assessment of the Sturt Plateau – Geophysical Investigation”, Natural Resources Division Internal Report 32/2000D, Darwin (2000).

2. Day, K.J., Sivertsen, D.P. and Torlach, D.A., “Land Resources of the Sturt Plateau, Northern Territory – A Reconnaissance Land System Survey”, Land Conservation Unit, Conservation Commission of the Northern Territory, Darwin (1985).

3. Greentree, D. and Jackson, L., “Earthmovers Training Course”, Soil Conservation Service of NSW, Chatswood (1991).

4. Nelson, K.D., "Design and Construction of Small Earth Dams", Inkarta Press, Melbourne (1985).

8.0 GLOSSARY

AMG EASTING	The east-west coordinates of the bore in metres from the grid's origin. It refers to the grid lines on the map.
AMG NORTHING	The north-south coordinates of the bore in metres from the grid's origin. It refers to the grid lines on the map.
AQUIFER	A body of rock that is sufficiently permeable to transmit 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	Lined hole constructed with a drilling rig and which is used to extract groundwater.
BORE DIAMETER	The minimum internal bore diameter in millimetres
BORE REGISTERED NUMBER (RN)	A number assigned by the Natural Resources Division to each registered bore.
BUND	Bank constructed of compacted fill used to contain water.
CASING	Tubing used to line boreholes. The length of casing in the hole is expressed in metres and its internal diameter in millimetres.
DEMAND	The volumetric flow rate required for stock watering therefore the rate at which water would be supplied if available.
DEPTH DRILLED	The total depth of the bore in metres below ground level.
DISSOLUTION	The process where rock has been dissolved by water and the component parts are carried in solution.
GROUNDWATER	Water contained in rock below the water table.

KARSTIC	Term which denotes the characteristic scenery of a limestone region.
OFF-STREAM TANK	Excavated tank built near creeks and connected to the creek by a channel to tap the creek flow.
ON-STREAM TANK	Excavated tank built in the bed of a well defined stream.
PERENNIAL	Lasting throughout the year, or through many years.
PUMPING RATE	The recommended pumping rate in litres per second.
PUMP SETTING	The recommended depth below ground level at which the pump intake should be set.
SLOTS	The apertures located in the casing adjacent to the aquifer. An interval over which they exist is usually expressed between depths in metres below ground level.
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.
WATER TABLE	The surface resulting when the standing water levels in adjacent bores in the same aquifer are connected.
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.

APPENDIX 1

BORE TEST REPORTS

Test reports for bores within the region are included in this Appendix. Further details of the bore tests and other bore information is available from the Natural Resources Division in Darwin.

1. General Recommendations for Finishing, Operating and Protecting Groundwater Bores.

Attention to the following points will prolong the life of the bore supply and help prevent pollution of the groundwater resources.

a. Construct a concrete apron around the borehead to prevent surface flow and any spillage from entering the bore.

b. Seal the space between casing and pump equipment to prevent entry of small animals, insects, dirt and pollutants.

c. Maintain pumping equipment in good order to prevent pollution. Avoid spillage of fuel and oil on the ground around the bore.

d. Keep stock away from the bore head. Discourage domestic activity at the bore and store fertiliser and other chemicals at least 50 metres distant.

e. Pumping the bore at higher than recommended rates may cause sand intrusion and lead to instability or pump problems. Seek advice from this office or other qualified source.

f. When bore is not equipped or no longer required it should be securely capped. If the bore is to be abandoned, the casing may need to be removed, the bore backfilled and cement plugs placed.
NB. This requires the services of a registered driller

Please ensure that the BORE IDENTIFICATION TAG is retained securely at all times. The registered bore number, RN, is the Natural Resources Division's only reference to the scientific and engineering data on this bore and hence important to this Division’s records for advice to bore owners.

NATURAL RESOURCES DIVISION
TEST REPORT – RN 31963

Bore Location: Hidden Valley Station
Map: MIDDLE CREEK 1:100,000 Sheet: 5465
Grid Reference: AGD 66 0243051- 8199374

Client: Natural Resources
Purpose: Investigation

****

RECOMMENDATIONS: Pumping Rate: 2.3 L/s **Pump Setting: 100.0 m**

For alternative pumping rates or settings contact:
General recommendations are on reverse side.
In all correspondence please quote **RN 31963**

Natural Resources Goyder Centre
25 Chung Wah Tce.
Palmerston NT 0831

****

Bore Data:

Finished depth: 137.0 m Completion date: 14.8.00
Standing Water Level: 88.78 m on 7.9.00
Construction Details:

Test Date: 8.9.00
Test Rate: 2.3 L/s
Test Duration: 500 minutes

Interval	Description
0.0 - 5.5 m	**202 mm ID steel casing**
0.0 - 120 m	**154 mm ID steel casing**
120 - 137 m	**open hole**

Notes: 1. Top of casing when tested was 0.75 m above ground.
2. All depths are measured from natural ground level unless stated otherwise.
3. Test rates do not necessarily indicate a sustainable yield for production pumping.

WARNING: MINIMUM INTERNAL BORE DIAMETER IS 154 mm
MINIMUM INTERNAL BORE DIAMETER TO RECOMMENDED PUMP SETTING IS 154 mm

****

COMMENTS:

1. The above recommendations are based on a multi rate test at up to 2.3 L/s for 500 minutes and assume that hydrological conditions remain constant.
2. Provision to monitor water levels and obtain water samples should be incorporated when equipping bore.
3. Casing suspended by annular ring.
4. This bore is capable of higher yields. For further advice contact Natural Resources.

****

WATER ANALYSIS: Lab register # 1354 & 1355

Prepared by: D Spencer
14.9.00

Checked by: D Low
15.2.01

NATURAL RESOURCES DIVISION
TEST REPORT – RN 32463

Bore Location: Hidden Valley Station
Map: DALY WATERS 1:100,000 Sheet: 5565
Grid Reference: WGS 84 0297850- 8195956

Client: Natural Resources
Purpose: Investigation

****

RECOMMENDATIONS: Pumping Rate: N/A **Pump Setting: N/A**

For alternative pumping rates or settings contact:
General recommendations are on reverse side.
In all correspondence please quote **RN 32463**

Natural Resources Goyder Centre
25 Chung Wah Tce.
Palmerston NT 0831

****

Bore Data:

Finished depth: 84.7m Completion date: 27.11.99
Standing Water Level: 60.34 m on 20.9.01
Construction Details:

Test Date: 20.9.01
Test Rate: up to 3L/s
Test Duration: 22.5 hours

Interval	Description
0.0 - 5.6 m	**203 mm ID steel casing**
0.0 - 78.6m	**154 mm ID steel casing**
78.6 - 84.7m	**154 mm ID steel casing, 4mm oxy slots**
87.7 - 99.7m	**154 mm ID steel casing**

Notes: 1. Top of casing when tested was 0.65 m above ground.
2. All depths are measured from natural ground level unless stated otherwise.
3. Test rates do not necessarily indicate a sustainable yield for production pumping.

WARNING: MINIMUM INTERNAL BORE DIAMETER IS 154 mm
MINIMUM INTERNAL BORE DIAMETER TO RECOMMENDED PUMP SETTING IS 154 mm

****

COMMENTS:

1. The above recommendations are based on a multi-rate test at up to 3L/s for 22.5 hours and assume that hydrological conditions remain constant.
2. It is recommended that provision to monitor water levels and obtain water samples should be incorporated when the bore is equipped.
3. The bore forked at 3 L/s after 4 minutes of pumping. A rate of 1.2 L/s of clean pumping was achieved before this increase in rate.
4. This bore is NOT recommended due to intrusion of silt and sand.
5. For further advice, contact Natural Resources Division

****

WATER ANALYSIS: Lab register : TBA

Prepared by: R. Setchell
Date: 20.9.01

Checked by: D. Low
Date: 4.10.01

NATURAL RESOURCES DIVISION
TEST REPORT – RN 32464

Bore Location: Hidden Valley Station
Map: MIDDLE CREEK 1:100,000 Sheet: 5465
Grid Reference: AGD 66 53K 0272833- 8197519

Client: Natural Resources
Purpose: Investigation

****

RECOMMENDATIONS: Pumping Rate: 0.5 L/s **Pump Setting: 85m**

For alternative pumping rates or settings contact:
General recommendations are on reverse side.
In all correspondence please quote **RN 32464**

Natural Resources Goyder Centre
25 Chung Wah Tce.
Palmerston NT 0831

****

Bore Data:

Finished depth: 99.7m Completion date: 11.8.00
Standing Water Level: 70.28 m on 18.9.00
Construction Details:

Test Date: 9.9.01
Test Rate: 0.5 L/s
Test Duration: 1.6 hours

Interval	Description
0.0 - 5.60 m	**202 mm ID steel casing**
0.0 - 73.20m	**154 mm ID steel casing**
73.2 - 81.70m	**154 mm ID steel casing, 4mm oxy slots**
81.7 - 93.70m	**154 mm ID steel casing**
93.7 - 99.70m	**Open Hole**

Notes: 1. Top of casing when tested was 0.50m above ground.
2. All depths are measured from natural ground level unless stated otherwise.
3. Test rates do not necessarily indicate a sustainable yield for production pumping.

WARNING: MINIMUM INTERNAL BORE DIAMETER IS 154 mm
MINIMUM INTERNAL BORE DIAMETER TO RECOMMENDED PUMP SETTING IS 154 mm

****

COMMENTS:

1. The above recommendations are based on a multi-rate test at up to 0.5 L/s for 1.6 hours and assume that hydrological conditions remain constant.
2. It is recommended that provision to monitor water levels and obtain water samples should be incorporated when the bore is equipped.
3. This bore underwent workover on 9.9.01. The casing was pulled back 6m and is suspended by annular ring.
4. Note that the recommended pump setting is below the slots.
5. For further advice, contact Natural Resources Division.

****

WATER ANALYSIS: Lab register # 1356 & 1357

Prepared by: R. Setchell
19.9.01

Checked by: D Low
4.10.01

APPENDIX 2

CHEMICAL ANALYSES OF GROUNDWATERS

The following table lists chemical analyses of bores sampled in this area of the Sturt Plateau. See Appendix 3 for quality guideline limits for stock and domestic consumption.

Table 2 Water Quality Data

Bore RN	Sample Date	Conductivity (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarbonate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
555	01/11/55				525	484	1396	47	305		65		42	222	189	0.74			
555	03/10/68	1900	7.5	328	200	445	1070	39	305		58		31	245	198	0.8	0.1		pumped as equipped
555	10/05/70	1010	8.2	172	210	335	650	37	100	165	59		10	73	183	0.9	4.1		
556	28/08/68	2100	7.2	312	190	640	1315	175	465		70		24	240	175	0.6	0.2		
556	10/06/70	2200	8.3	410	500	726	1650	160	520	852	77		21	252	176	0.5	0.5		pumped as equipped
557	11/11/55				588	550	1562	110	310		67		42	235	206	0.4			
557	17/10/68	1900	7.4	362	221	540	1150	42	305		60		31	240	205	1	0.2		
558	02/10/68	1550	7.4	308	188	430	940	43	254		53		22	180	138	0.7	0.1		pumped as equipped
558	09/05/69	1800	6.9	434	529	448	1130	130	266		54		24	210	157	0.5	0.5		
558	19/02/72	1850	7.4	446	544	577	1120	137	272		57	6	21	180	161	0.7	0.1	31	pumped as equipped
558	08/03/76	1980	6.9	415	506	566	1060	136	280	461	55	7	22	184	182	0.4	0.1	38	pumped as equipped
1982	06/06/98	702	6.3	401	489	392	398	101	2	3	34	1	5	3	11	0.1	0.7	28	0.5L/s, pumped as equipped
4529	12/10/64	1000	7.4	140		44	794		288										
4529	11/06/66	1670	6.9	527	321	690	1390	97	254		107		28	215	80	0.1	0.44		
4529	11/10/68	1800	7.9	1080	344	505	1080	65	295		81		22	210	203	0.8	0.3		pumped as equipped
5395	05/04/66	1900	7.2	466	284	498	1193	115	269		50		34.5	233	234	0.3	0.1		
6223	15/07/99	2240	7.1	445	543	632	1370	148	334	550	64	7	27	240	230	0.4	0.8	38	pumped as equipped, est 2L/s
7191	11/11/70	1000	7.6	249	303	307	640	54	134		42	2	28	102	130	0.7	4.6	28	53m
7192	11/11/70	1140	7.7	274	334	341	680	59	136		47	2	18	105	126	0.6	0.2	29	1.5L/s, 58m, pumped as equipped
7321	10/10/71	1360	8.1	308	376	327	800	37	204		57	4	30	159	146	0.5	0.1	41	3L/s, 58m, pumped as equipped

Table 2 Water Quality Data (continued)

Bore RN	Sample Date	Conductivity (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarbonate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
7686	28/07/71	1180	7.8	490	598	536	720	129	72		51		9	52	105	0.5	10		
7687	28/07/71	1210	7.5	442	539	520	760	129	89		48	1	62	48	134	0.5	6.4	29	pumped as equipped
7687	03/10/71	1050	7.4	296	361	400	610	78	97		50	1	11	65	129	0.5	9	30	pumped as equipped
7725	03/10/71	1160	7.5	404	493	488	710	118	85		47	1	10	62	113	0.5	2.9	29	
7755	03/10/71	800	7.4	363	443	390	470	87	30		42		6	24	52	0.4	0.9		
7872	19/05/72	900	8.1	187	228	364	620	52	90	148	57		10	64	205	0.2	1		1.5L/s, 102m, airlift
7872	01/11/99	1210	7.5	453	552	512	744	126	102	168	48	1	9	67	140	0.4	0.1	31	pumped as equipped, est 2L/s
7873	30/05/72	960	8.2	156	190	289	640	33	125	206	50	1	18	93	185	0.7	5	45	2L/s, 102m, airlift
7873	17/03/80	560	7.3	248	302	252	264	58	7	12	26		1	5	11	0.1	0.1		0.6L/s
7873	01/11/99	981	7.5	395	482	443	634	110	57	94	41	6	7	40	89	0.3	0.2	32	pumped as equipped, est 2L/s
7875	24/05/72	950	8.1	211	257	285	570	36	122	204	47	2	16	90	115	0.6	5.7	33	1.5L/s, 100m, airlift
7876	01/11/99	1470	7.4	425	518	589	906	139	188	310	59	1	7	87	150	0.3	0.1	32	pumped as equipped, est 2.5L/s
8017	10/10/72	1590	8.2	262	320	331	930	34	269	443	60	1	32	200	176	0.4	0.8	59	airlift
8856	17/05/76	1650	7.1	399	486	509	960	120	194	320	51	3	23	150	148	0.4	0.5	38	19.4L/s, pumped
8856	17/05/76	1880	7.5	407	496	521	1110	118	243	400	55	6	29	183	178	0.4	0.3	40	19.1L/s, pumped
8856	17/05/76	1990	7.3	387	472	533	1180	118	272	448	58	6	31	195	196	0.5	0.4	41	19.1L/s, pumped
8856	17/04/84	1800	8.2	431	526	576	1060	135	250	409	58	6	24	169	148	0.2	0.2	40	pumped as equipped
8856	19/09/85	1800	6.9	428	521	557	1140	129	240	390	57		20	154	151	0.3	0.6		pumped as equipped
8856	14/07/89	2130	7.3	458	559	555	1295	122	320	527	61	9	35	268	222	0.5	0.1	42	pumped as equipped
8856	08/06/98	2103	7.3	460	561	558	1281	120	305	503	63	8	31	230	230	0.4	0.2	39	2L/s, pumped as equipped

Table 2 Water Quality Data (continued)

Bore RN	Sample Date	Conductivity (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarbonate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
23377	02/08/84	1970	7.3	306	373	409	1220	65	330	539	60	1	30	242	246	0.4		31	2L/s, 81m, airlift
24815	04/05/87	850	7.2	400	488	407	490	97	21	35	40		7	16	24	0.2	0.2		3L/s, 157m, airlift
24815	04/05/87	830	7.3	389	474	393	465	93	22	36	39		6	16	24	0.2	0.6		3L/s, 157m, airlift
24816	14/05/87	850	7.1	408	498	440	505	104	23	38	44	1	5	13	20	0.4	0.6	37	6.6L/s, 192.5m, airlift
24816	14/05/87	840	7.2	402	490	410	470	103	22	36	37	1	5	12	19	0.4		35	6L/s, 192.5m, airlift
24817	11/05/87	800	7.3	340	415	357	430	85	27	45	35	1	6	22	33	0.5	1	26	8L/s, 201.5m, airlift
27328	07/05/91	1865	7.4	318	387	523	1120	112	350	577	59	5	21	205	152	0.2	6.3	38	1.5L/s, 77m, airlift
27328	15/07/99	2160		468.0	571	625	1290	150	352	580	61	6	20	199	180	0.3	0.1	39	pumped as equipped
27331	01/11/90	630	7.2	291	355	274	360	57	27	44	32	3	7	25	20	0.7	4	26	0.1L/s, 117m, pumped
27331	05/06/98	702	6.4	357	435	343	412	78	15	25	36	1	6	21	25	1.3	0.1	42	0.3L/s, pumped as equipped
27341	05/06/98	750	6.4	422	515	421	430	111	3	5	35	1	3	5	12	0.2	0.1	32	2L/s, pumped as equipped
28314	25/06/93		7.8		397	435	670	102	83		44		8	80	114		0.1		
30870	03/08/96	464	7.2	166	202	223	296	48	6	10	25	2	3	5	28	0.2	0.5	21	2L/s, 78m, airlift
30870	05/06/98	674	6.3	382	466	376	389	111	2	3	24	1	3	2	10	0.1	0.1	22	1.5L/s, pumped as equipped
30871	05/08/96	487	7.4	232	283	266	296	49	3	5	35	1	3	3	12	0.3		27	
30871	24/08/99	748	7.4	430	524	426	432	108	2	3	38	1	3	4	17	0.1	0.1	27	1.4L/s, 86.8, pumped
30985	22/08/98	1944	7.7	338	412	438	1166	72	312	514	63	6	27	217	247	0.3	6.1	36	4L/s, 133m, airlift
30985	13/10/98	2021	7.3	409	499	559	1226	122	332	547	62	5	24	197	233	0.4	0.2	32	6L/s, 95m, pumped
32463	27/11/99	550	7.5	303	370	277	303	45	6	10	40	1	3	5	14	0.1		28	2L/s, 78m, airlift

APPENDIX 3

WATER QUALITY STANDARDS FOR STOCK AND DOMESTIC USE

1. WATER QUALITY STANDARDS FOR STOCK USE

SUBSTANCE	GUIDELINE VALUE
pH range	6.5 - 8.5
Total dissolved solids	10000mg/L
Sodium chloride	Not more than 75% when total dissolved solids near limit
Sulphate	2000mg/L
Nitrate	400mg/L
Fluoride	2.0mg/L
Magnesium	300mg/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, AUSTRALIAN DRINKING WATER GUIDELINES 1996)

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	500mg/L	#
Chloride	250mg/L	#
Sulphate	250mg/L	#
Nitrate	50mg/L	+
Fluoride	1.5mg/L	
Hardness (as Calcium Carbonate)	200mg/L	*
Sodium	180mg/L	*

(*) Values outside of the guidelines for pH and hardness may result in either build-up of scale in pipes or corrosion of pipes but they do not pose a health problem.
(#) Above these limits the taste may be unacceptable but they do not pose a health problem.
(+) For nitrate, a limit of 50mg/L is recommended for babies less than 3 months old, 100mg/L is the guideline for older children and adults.

APPENDIX 4

EXCAVATED TANK 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 booklet entitled "Design and Construction of Small Earth Dams" (Reference 4). 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 present leakage problems
- show if there is any impermeable and soft rock present, such as rippable hard clays or laterite
- 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 on-stream 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 sub-surface 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 5). 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, the water table will be deeper than the proposed 3 to 4 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.

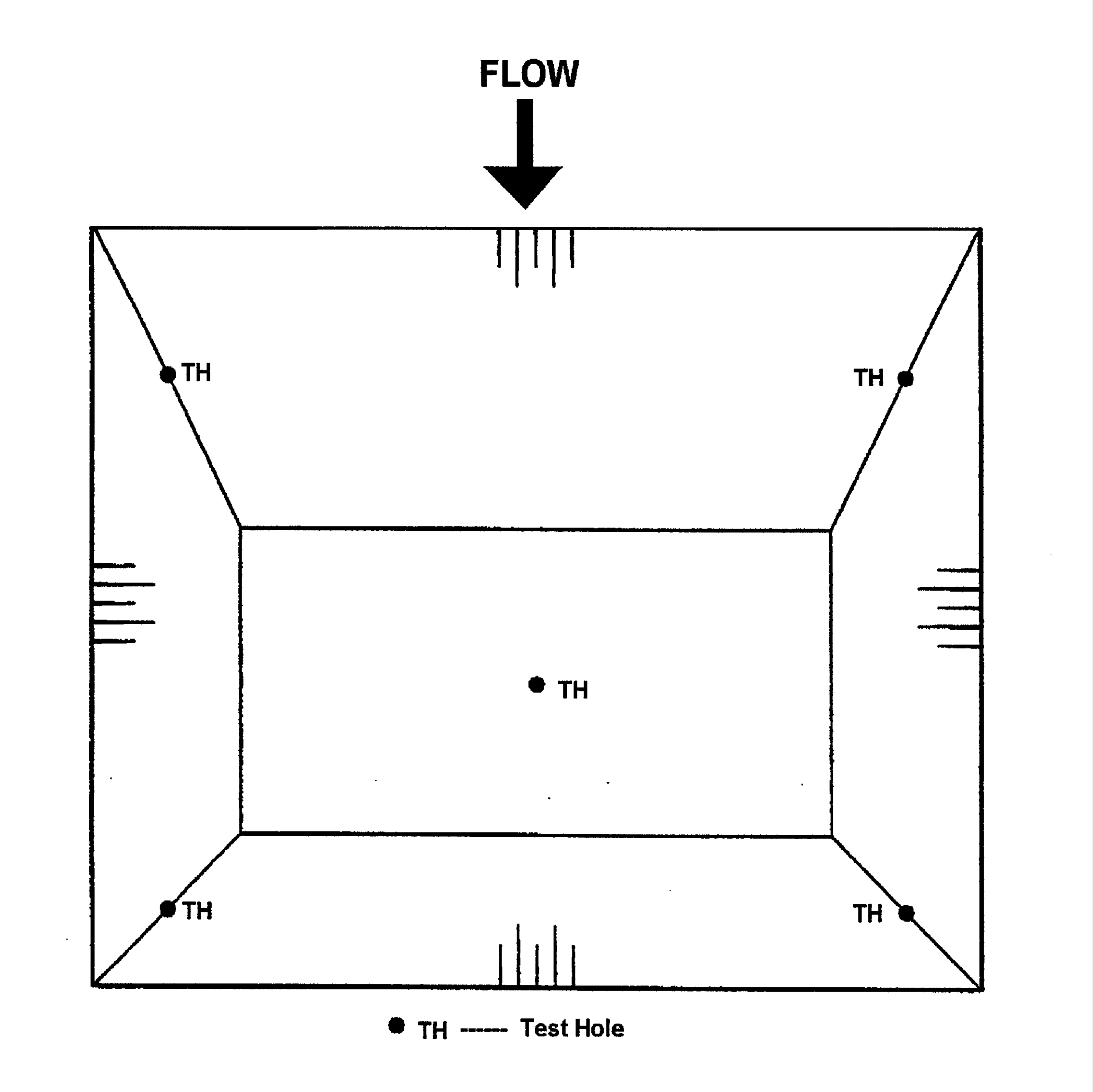

Figure 5 Test hole plan for an excavated tank

The following procedure is proposed but is only indicative:

- 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. Maintain the water at this level by topping up as necessary.
- The test is a measurement of the amount of water needed to maintain the water level at 0.5 metres below ground level for one day. Once the test is commenced, the amount of water added is recorded. This should continue 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 site is considered doubtful. Some work would be needed to limit the water loss rate or to increase the sealing capacity of the tank floor (eg. use plastic liner or clays). Seepage 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 ranging 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 a soil laboratory to provide confirmation of soil suitability. However, simple field tests can give a good indication for the likely behaviour of the soils.

- 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.

- 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 one litre 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.

- 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 that 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 also be necessary to abandon the proposed site.

APPENDIX 5

CONSTRUCTION DETAILS OF EXCAVATED TANKS, TURKEY NESTS AND MODIFIED WATERHOLES

Assume preliminary investigations (Appendix 4) have been conducted and indicate that suitable conditions exist for the proposed construction. The integrity of the structure now hinges on the construction methods utilised.

1. Drainage-Line 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 the storage capacity. The bund should have a minimum berm width of 5 metres (Figure 3). Topsoil with potential for leakage must be removed down to an impervious layer before the bund is built, and compaction may be undertaken using the available machinery. The ideal time to achieve optimum compaction is early in the dry season 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.

Catch drains can also be constructed (eg. using a tilted grader blade) to effectively increase the interception capacity 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 quite sound although special attention should be paid to:

- removal of leaky topsoil from the base before construction
- the selection of a non-dispersive soil as the construction material
- compaction at optimum moisture content. This can be achieved if construction is undertaken early in the dry season while the soil is still moist. Every 100 mm layer of loose soil should be compacted.

The table below gives examples of recommended dimensions, sized for turkey nests of a three day water supply capacity.

Number of Cattle	Inner Diameter At Base (m)	Inner Diameter at Top (m)	Total Height of Turkey Nest (m)	Draught (m)
250	4	13	1.8	0.8
400	6	15	1.8	0.8
600	6	16	2.0	1
1000	6	18.5	2.5	1.5

These figures are based a slope of 1 in 2.5 for the inner sides. The capacity of the tank (in terms of number of cattle) allows for leakage, the overflow standpipe to be 0.5m below the top of the tank and the outlet pipe supported 0.5m above its base. The draught is the depth of available water in the tank and is effectively the tank's storage capacity.