Daly River Catchment

Water Balance

REPORT 10/2002

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DLPE

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Contents

List of Figures

List of Tables

1. Introduction

The aims of this document are:

1. To provide an overview of the current state of knowledge of the water balance for the Daly River Catchment; and
2. To document work that is required to improve our understanding of the components of the water balance, both areally and with time.

The Daly River catchment covers an area of approximately 52,600 square kilometres. Its extent is shown on Figure 1. Data has been collected on various aspects of the surface water and groundwater hydrology of the Catchment for at least the last 50 years.

2. What is a Water Balance?

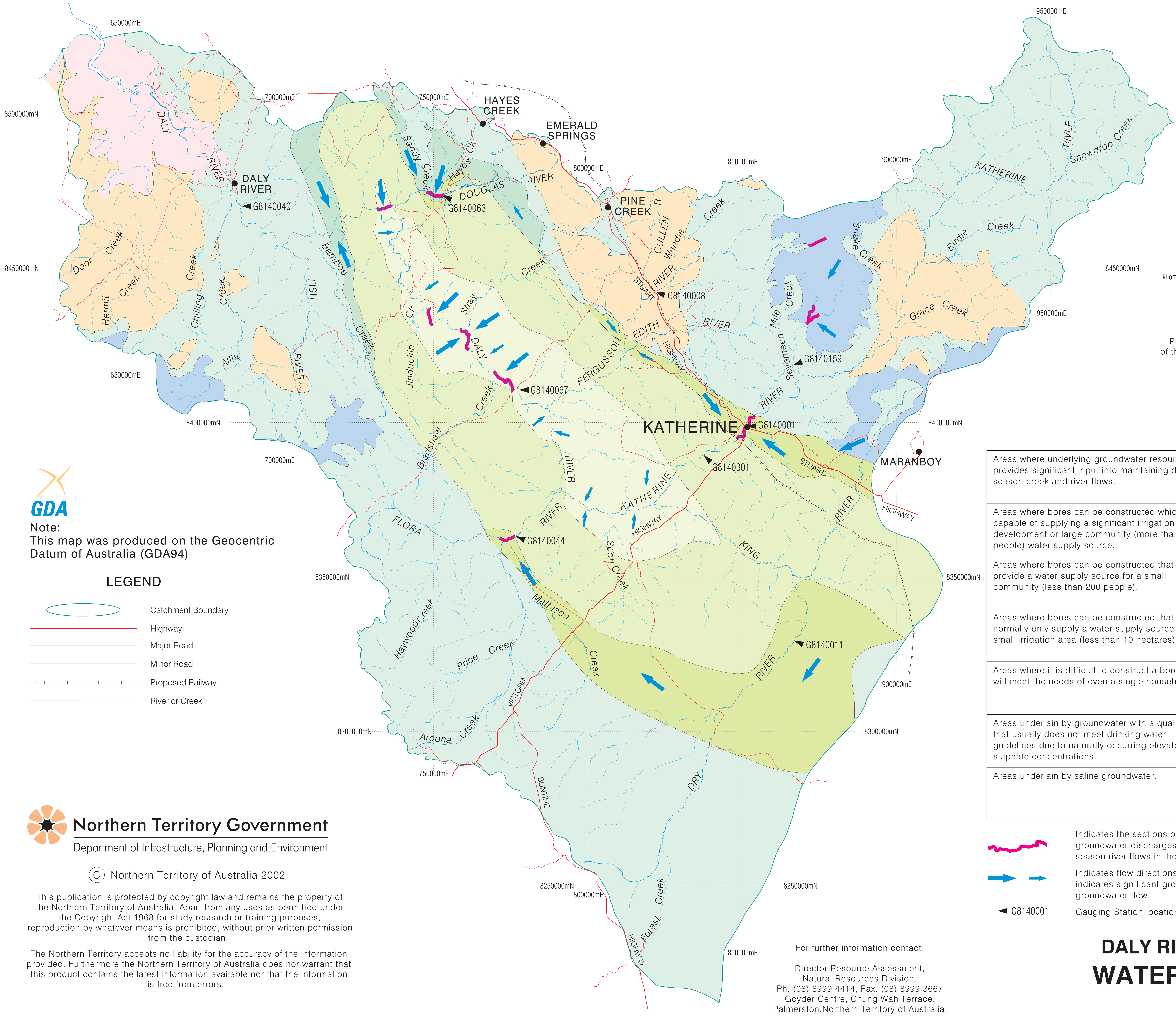
A water balance is a summary of the current state of knowledge of the inflows and outflows of water within a catchment. The water balance takes into account any temporary storage of water within the catchment.

The various components of the water balance, as they apply to the Daly River catchment, are summarised in the following Table.

Table 1. Components of a Water Balance

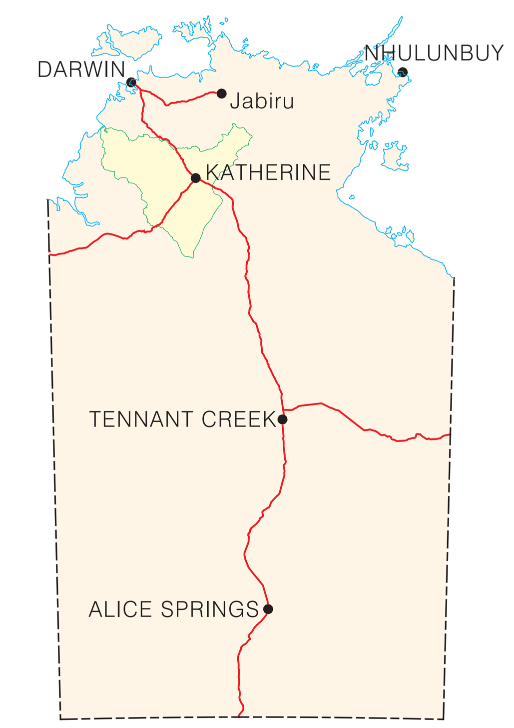
Inflow	Outflow	Storage
Rain	Runoff	Reservoir storage
Inflows from adjacent groundwater resources	Evaporation and Transpiration	Water stored above and below the water table
	Pumping	

The following sections provide an overview of the current state of knowledge of these various components.



LOCALITY PLAN

Not to Scale



kilometres 10 0 10 20 30 40 50 kilometres

Black numbered lines are 50000 metre intervals of the Map Grid of Australia (MGA), Zone 52
Projection: Universal Transverse Mercator
Horizontal Datum: GDA94

Prepared and produced by the Natural Resources Division of the Department of Infrastructure, Planning and Environment, Darwin, Northern Territory of Australia.

February 2002

Design File: Daly_Cthmt_wrs_mga52.dgn
Plot File: Daly_Cthmt_wrs.plt

GDA

Note:
This map was produced on the Geocentric Datum of Australia (GDA94)

LEGEND

- Catchment Boundary
- Highway
- Major Road
- Minor Road
- Proposed Railway
- River or Creek

Areas where underlying groundwater resource provides significant input into maintaining dry season creek and river flows.								
Areas where bores can be constructed which are capable of supplying a significant irrigation development or large community (more than 200 people) water supply source.								
Areas where bores can be constructed that could provide a water supply source for a small community (less than 200 people).								
Areas where bores can be constructed that would normally only supply a water supply source for a small irrigation area (less than 10 hectares).								
Areas where it is difficult to construct a bore that will meet the needs of even a single household.								
Areas underlain by groundwater with a quality that usually does not meet drinking water guidelines due to naturally occurring elevated sulphate concentrations.								
Areas underlain by saline groundwater.								

Indicates the sections of a creek or river into which a significant amount of groundwater discharges. These groundwater discharges maintain the dry season river flows in the Katherine, Flora and Daly Rivers.

Indicates flow directions within the highest yielding aquifers. A large arrow indicates significant groundwater flow, a small arrow indicates less significant groundwater flow.

G8140001 Gauging Station location and number

Northern Territory Government
Department of Infrastructure, Planning and Environment

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DALY RIVER CATCHMENT
WATER RESOURCES

3. Rain

Nearly all of the water entering the Daly River Catchment does so as rainfall. The whole of the catchment comes under the impacts of the monsoon, as well as intense rain depressions resulting from decaying tropical cyclones. This results in a rainfall that is highly variable. Katherine's daily rainfall record since 1940 has been plotted on Figure 2 to illustrate this variability in intensity throughout the year and from year to year. Katherine's daily rainfall record is continuous since 1884. Annual (October to September) rainfall totals vary from a low of 364 mm (1951/52) to a high of 1990 mm (1897/98). Annual rainfall totals for the full period of record are plotted on Figure 3.

The impact of the monsoon results in over 90% of Katherine's mean annual rainfall of 980 mm occurring between the months of November and March. The mean annual rainfall increases slightly to the north to approximately 1100 mm near the Douglas Daly Research Station and decreases slightly to the south west of Katherine to about 900 mm in the Dry River area. The seasonal variability across the catchment will be similar to that shown in Table 2 for Katherine with monthly values being up to 10% higher or lower.

Table 2 Mean Monthly Rainfall – Katherine PO DR014902

Month	Rainfall (mm)
October	30
November	90
December	195
January	243
February	210
March	165
April	30
May	5
June	2
July	2
August	1
September	7

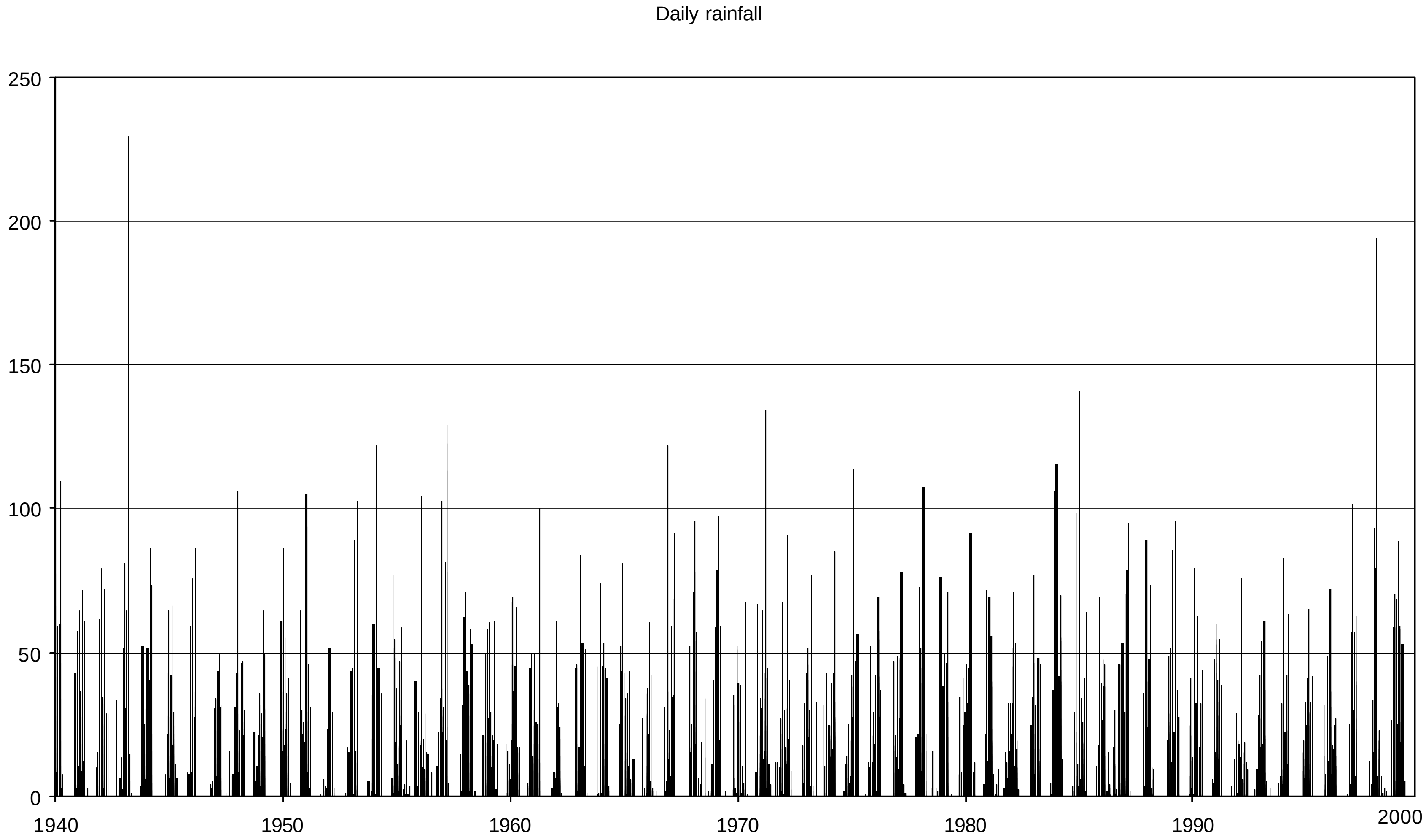


Figure 2. Daily Rainfall Data for Katherine PO DR014902 for Period 1940 to 2000

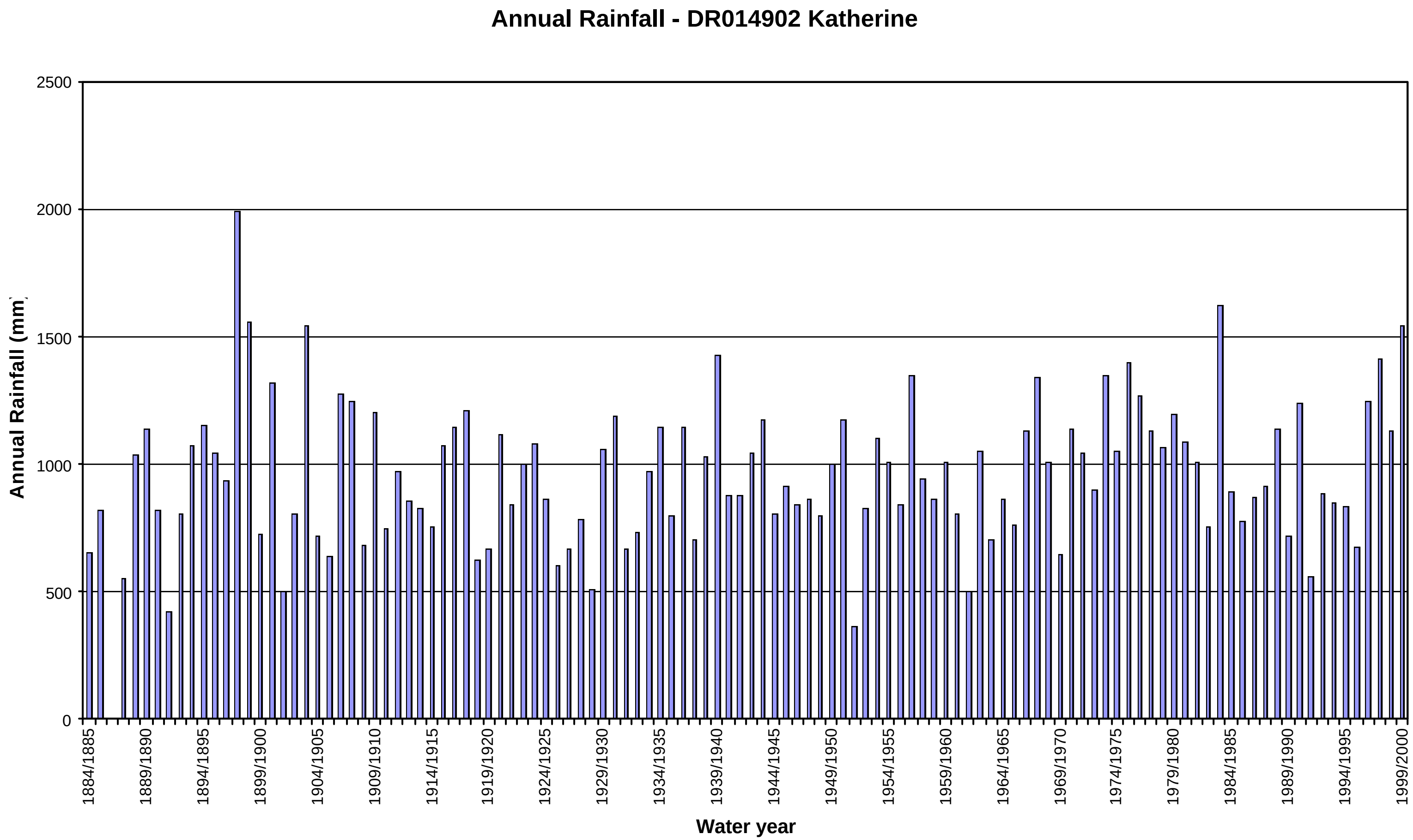


Figure 3. Annual (Oct – Sep) Rainfall Data for Katherine PO DR014902 for Period 1884/85 to 1999/2000

4. Inflows from Adjacent Groundwater Resources

Over most of the Daly River catchment small quantities of groundwater flow either into or out of the catchment within aquifers that occur adjacent to the catchment boundary. It would be expected that over most of the catchment the inflows will balance the outflows and the nett impact will not be significant..

The only exception to this is the aquifer system that provides the source of dry season flow in the Flora River. It would be expected that approximately 50% of the groundwater fed flow in the Flora River is sourced from recharge that occurs outside of the Daly River catchment. This recharge occurs across the Sturt Plateau to the south east of the Dry River.

5. Runoff

Runoff has been measured at a number of locations throughout the catchment. This overview presents data from

1. Those stations with more than 25 years of data that have significant dry season river flows; and
2. Two other representative stations that have more than 25 years of data and have flow records that are typical of larger river systems that stop flowing during each dry season.

The following table indicates the period of record and number of gaugings that have been recorded at each site. A qualitative statement has also been made regarding the quality of data relating to groundwater-fed dry season flows at each site. The location of each site is also shown on Figure 1.

Table 3. Gauging Station Details

Location	Number of GS	Period flows gauged	Number of Gaugings	Quality of low flow records
Katherine River -Low Level	G8140001	1952 – 1999	290	Good
Ferguson River	G8140008	1953 – 1996	135	No dry season flow
Dry River	G8140011	1971 – 1995	55	No dry season flow
Daly River - Mount Nancar	G8140040	1966 – 1999	287	Good
Flora River	G8140044	1966 – 1999	27	Poor
Douglas River	G8140063	1957 – 1997	280	Moderate
Daly River upstream of Dorisvale Crossing	G8140067	1957 – 1998	240	Good
Seventeen Mile Creek	G8140159	1961 – 2000	252	Moderate
Katherine River at Galloping Jacks	G8140301	1974 – 1998	67	Good

Runoff can be divided into three components:

1. Overland flow and interflow - Due to the highly permeable nature of the soil profile over most of the catchment, true overland flow rarely occurs, except following very intense rainfall events. Most water spends some part of its flow path from where it has fallen to the nearest small creek beneath the ground. Almost all of the flow above 10 cumecs in the following hydrograph (Figure 4) for the Katherine River is overland flow and interflow.

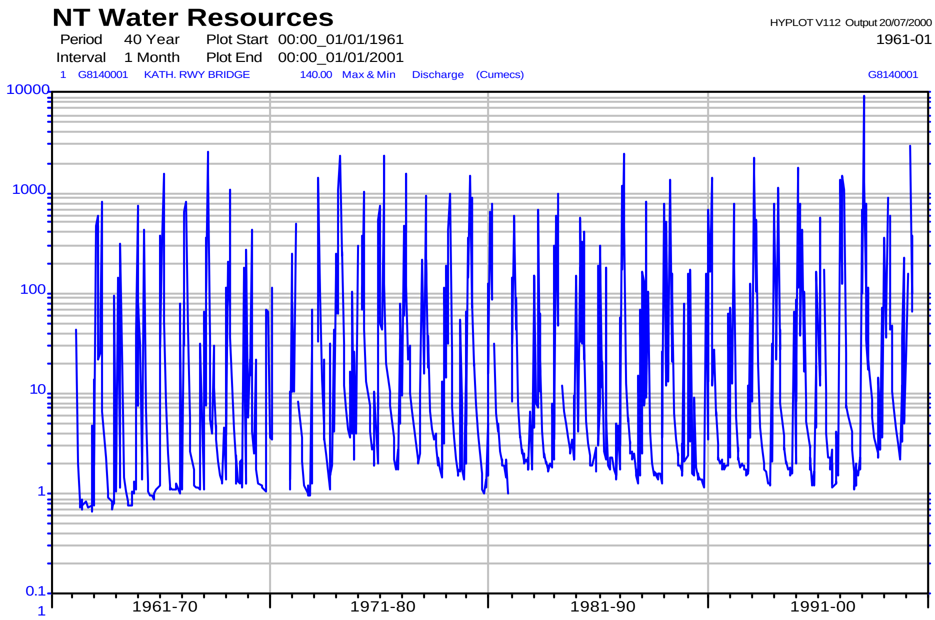


Figure 4. Discharge Hydrograph for the Katherine River at G8140001

2. Groundwater discharge from offstream bank and aquifer storage – When the level of the water in a river exceeds the water level in the aquifer beneath and adjacent to the river, water discharges from the river to the aquifer. The higher the level in the river, and the higher the permeability of the river sediments and strata comprising the aquifer, the greater the amount of water that moves into the aquifer during a river flow event. This water then discharges into the river during the dry season. This process is illustrated by the data contained in Figure 5. Monitoring bore RN 22397 is located on the top of the levee bank adjacent to the Katherine River. Monitoring bore RN22001 is located 22 kilometres from the River. Both bores monitor water levels in the aquifer developed in the Tindall Limestone.

3. Groundwater discharge from regional aquifer systems.
   This is the discharge process by which diffuse recharge to the regional aquifer system discharges to adjacent creeks and rivers. This diffuse recharge mechanism also includes recharge via sinkholes and via the bed of creeks and rivers where the

water levels in the aquifer underlying the creek or river are below the bed of the creek or river (eg Dry River). This recharge mechanism is illustrated by the water level data for monitoring bore 20851 (refer Figure 6). This is a monitoring bore for the aquifer in the Tindall Limestone in the Douglas River area.

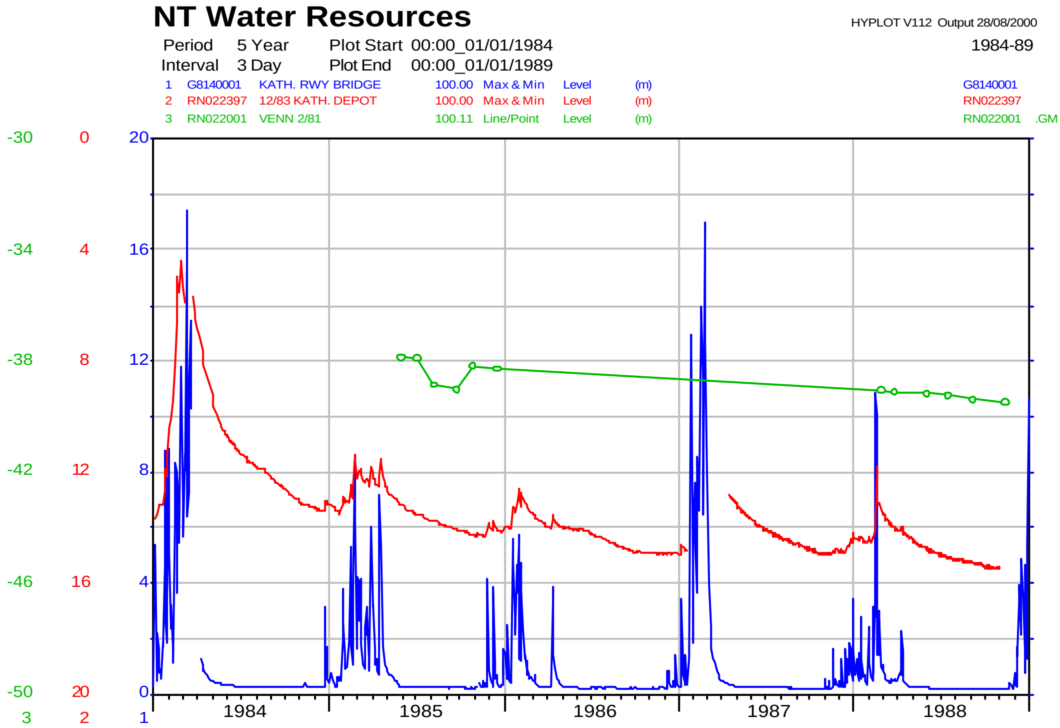


Figure 5. Katherine River – Tindall Limestone Aquifer Interaction

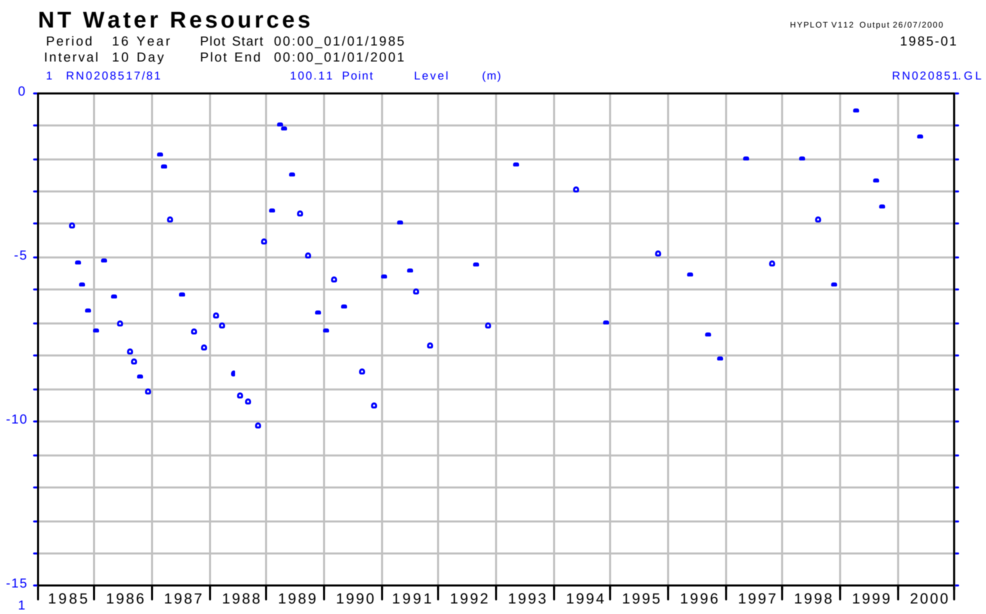


Figure 6. Water Level data for Bore RN 20851 in the Tindall Limestone

5.1 Annual Runoff from the Daly Basin

In this overview the first two runoff components - overland flow and interflow, and groundwater discharge from offstream bank and aquifer storage – will be considered as surface water runoff. The third component - groundwater discharge from regional aquifer systems – will be considered separately as regional groundwater discharge. The total annual runoff that represents the outflow from the Daly River Catchment is that recorded at the river gauging station G8140040 near Mount Nancar. This station is located on the Daly River just above the upper tidal limit on the Daly River (refer Figure 1). The values for total annual runoff given in Table 4 have been derived from hydrographs, rating curves and flow gaugings. The values for regional groundwater discharge are based on the mean annual instantaneous flow rate being 20% more than the minimum annual flow rate. The values for surface water runoff have been derived by subtracting regional groundwater discharges from the total annual runoff.

Table 4. Components of Runoff at G8140040 on the Daly River

Year (October to September)	Total Annual Runoff (x 10^5 ML)	Surface Water Runoff (x 10^5 ML)	Regional Groundwater Discharge (x 10^5 ML)
1969/70	10	7	3
1970/71	32	29	3
1971/72	58	55	3
1972/73	NA	NA	3
1973/74	147	136	11
1974/75	75	67	8
1975/76	172	164	8
1976/77	NA	NA	8
1977/78	33	26	7
1978/79	40	34	6
1979/80	86	80	6
1980/81	70	62	8
1981/82	37	31	6
1982/83	21	15	6
1983/84	108	101	7
1984/85	NA	NA	7
1985/86	13	8	5
1986/87	62	57	5
1987/88	16	11	5
1988/89	62	56	6
1989/90	11	6	5
1990/91	101	95	6
1991/92	22	17	5
1992/93	NA	NA	6
1993/94	70	64	6
1994/95	89	82	7
1995/96	25	20	5
1996/97	164	157	7
1997/98	110	102	8
1998/99	94	86	8
1999/2000	120	111	9

Note: NA indicates that the quality of the data was not good enough to calculate the annual flow.

The mean total annual runoff of 69 x 10^5 megalitres equates to a runoff of 148 mm. The mean surface water runoff of 63 x 10^5 megalitres equates to a runoff of 135 mm. The mean regional groundwater discharge of 6 x 10^5 megalitres equates to catchment wide effective recharge rate (ie in excess of evapotranspiration) of 13 mm.

5.2 Discussion on surface water runoff across catchment

Data has been extracted on total annual runoff and discharges from representative gauging stations across the Daly River Catchment to provide a basis for comment on surface water runoff. The data is presented in Tables 5 and 6.

Table 5. Annual Discharge Data

Gauging Station (G) `	Start of record	Catchment Area (km^2)	Annual Discharge (x 10^5 ML)		
			Min	Maximum	Mean
8140001 Katherine R	1957	8640	3.8	51	19
8140008 Ferguson R	1957	1490	0.7	12	4.4
8140011 Dry River	1970	6290	0.05	11	1.5
8140040 Daly R at Nancar	1969	46600	10	171	69
8140044 Flora River	1967	5900	1.8	28	8.6
8140063 Douglas River	1957	842	0.2	7.0	1.6
8140067 Daly R at Dorisvale	1961	35800	7.2	139	43
8140159 Seventeen Mile Creek	1963	619	0.2	3.2	0.9

Table 6. Annual Runoff Data

Gauging Station `	Start of record	Catchment Area (km^2)	Annual Runoff (mm)		
			Min	Maximum	Mean
G8140001 Katherine R	1957	8640	44	589	223
G8140008 Ferguson R	1957	1490	47	784	294
G8140011 Dry River	1970	6290	1	177	23
G8140040 Daly R at Nancar	1969	46600	21	362	148
G8140044 Flora River	1967	5900	31	470	146
G8140063 Douglas River	1957	842	24	826	185
G8140067 Daly R at Dorisvale	1961	35800	20	388	119
G8140159 Seventeen Mile Creek	1963	619	27	517	153

The Ferguson River runoff data is typical of rivers that obtain all their runoff from the sediments that flank the carbonate sediments of the Daly Basin (geological unit shown in various shades of green on Figure 1). These sediments have a low permeability and produce the highest surface water runoff of any of the sediments in the Daly River Catchment. A number of small to medium sized dam sites have been identified within this terrain. Sustainable yields of between 500 and 5000 Ml/year are typical for these type of dams. A number of potential larger dam sites have also been identified – Kekwick, Douglas, Nancar – with yields in excess of 5000 ML/year. Detailed studies have not been undertaken at any site.

The Dry River runoff data is typical of rivers that get the majority of their runoff from the carbonate sediments of the Daly Basin. Runoff is usually low unless the groundwater level rises to near to, or above, the surface. This only occurs in some areas close to the Katherine, Daly or Douglas Rivers in years of very heavy rainfall.

Hydrological studies have indicated that small dams may be constructed with yields of up to 1000 ML/year over the carbonate sediments. No detailed studies have yet been undertaken.

The Seventeen Mile Creek data is typical of creeks that get the majority of their runoff from the Cretaceous sediments (shown in blue on the accompanying map).

The data for the other rivers reflect runoff that originates from either two or all of the above types of sediments.

All rivers exhibit great variability in their maximum instantaneous flow rates, total annual runoff and variation in river water levels between the “wet” and “dry”. Data for G8140001 on the Katherine River and G8140040 and G8140067 is given in Figures 8, 9, and 10.

The maximum instantaneous flow rate at G8140001 in 1997/98 (refer Figure 7) has been determined to equate to an event with a 1 in 150 year return period flood event. It is more than double the next highest flow rate.

Data contained in Table 4 and Figure 8 indicate that the minimum annual surface water discharge from the Daly River Catchment, as measured at G8140040 for the period 1969/70 to 1999/2000, was 7 x 10 ^{5} cubic metres (15 mm runoff) in 1969/70 and 1989/90. The discharge of 8 x 10 ^{5} cubic metres in 1985/86 was the next lowest.

The maximum annual surface water discharge from the Daly River Catchment, as measured at G8140040 for the period 1969/70 to 1999/2000, was 165 x 10 ^{5} cubic metres (360 mm runoff) in 1975/76

The variation between highest and lowest river water level each year ranges from less than 15 metres to more than 20 metres at G8140001 on the Katherine River and G81400040 and G8140067 on the Daly River. Data given in Figure 9 for G8140001 indicates that rise in river water level of more than 12 metres is required before significant quantities of water discharge from the Katherine River to the aquifer developed in the Tindall Limestone. In the 41 year period shown on Figure 5, this occurred during approximately 50% of the years. At the higher levels the Daly River forms a flood plain that in places is many kilometres wide.

Little data exists on the hydrology of the lower coastal floodplains of the Daly River (area shown in pink on the accompanying map).

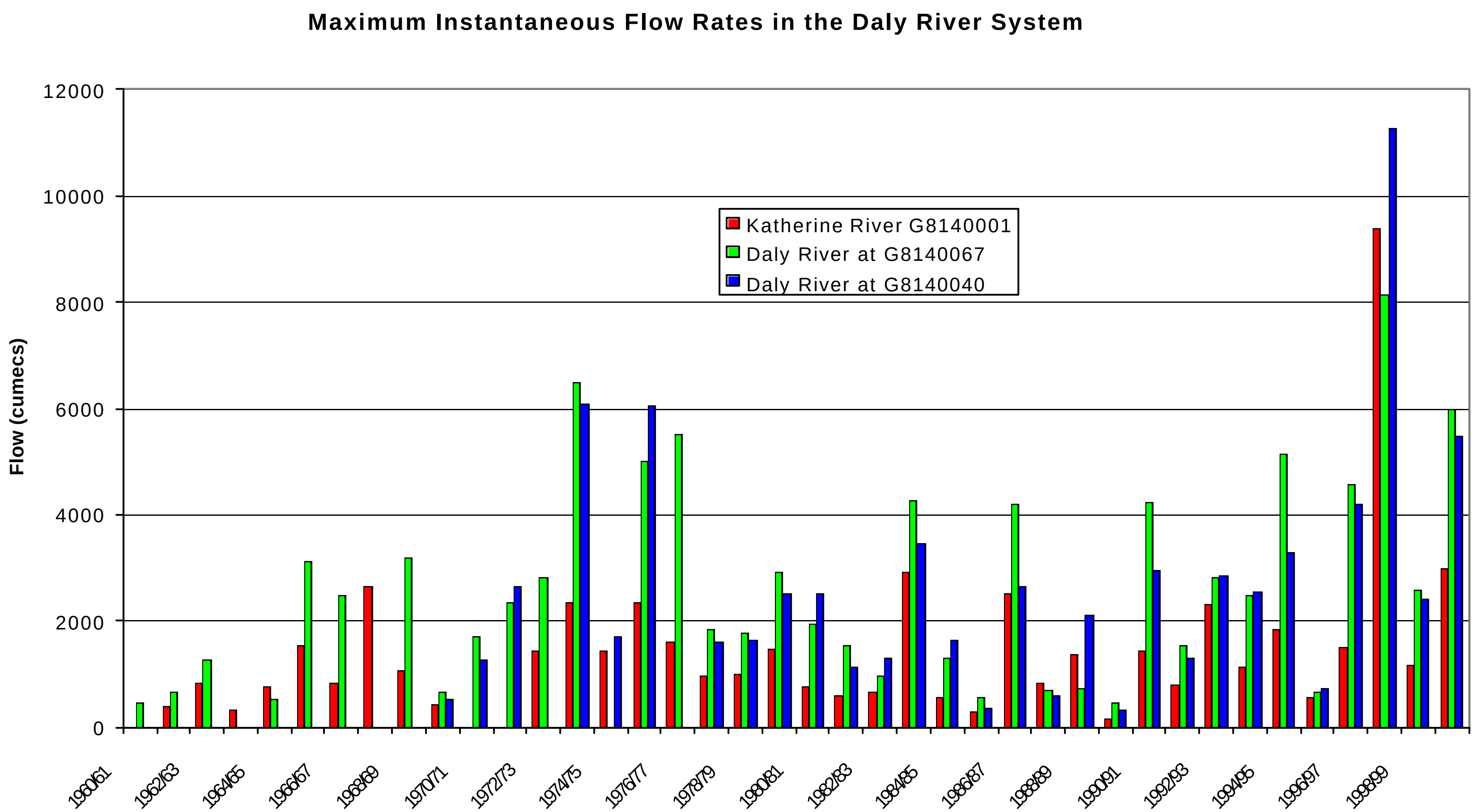


Figure 7. Maximum Instantaneous Flow Rate data for G8140001, G8140067 and G8140040

Note: Where no data is shown for a station for a year, it indicates that inadequate data exists to define data point

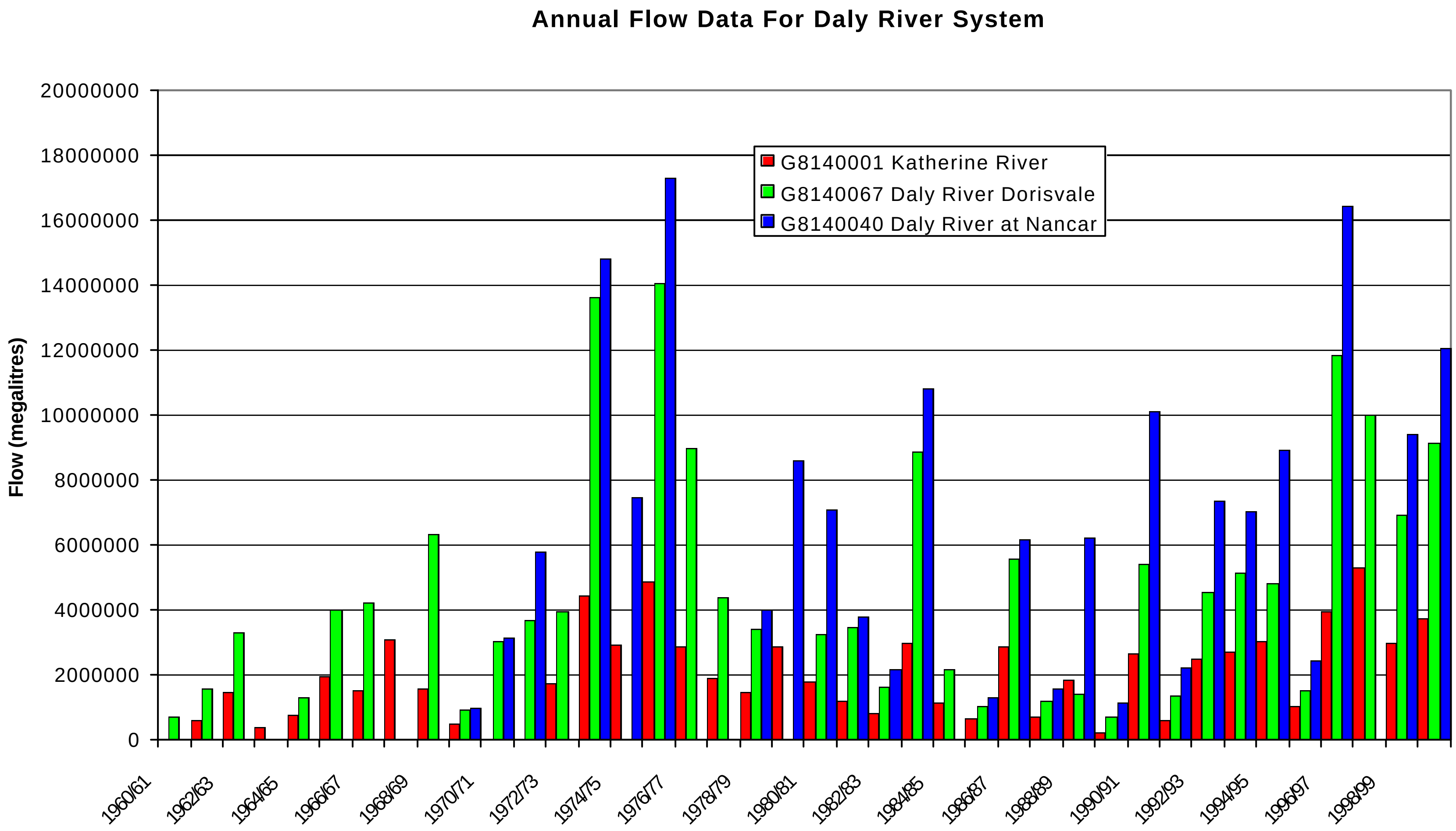


Figure 8. Annual Discharge data for G8140001, G8140067 and G8140040

Note: Where no data is shown for a station for a year, it indicates that inadequate data exists to define data point

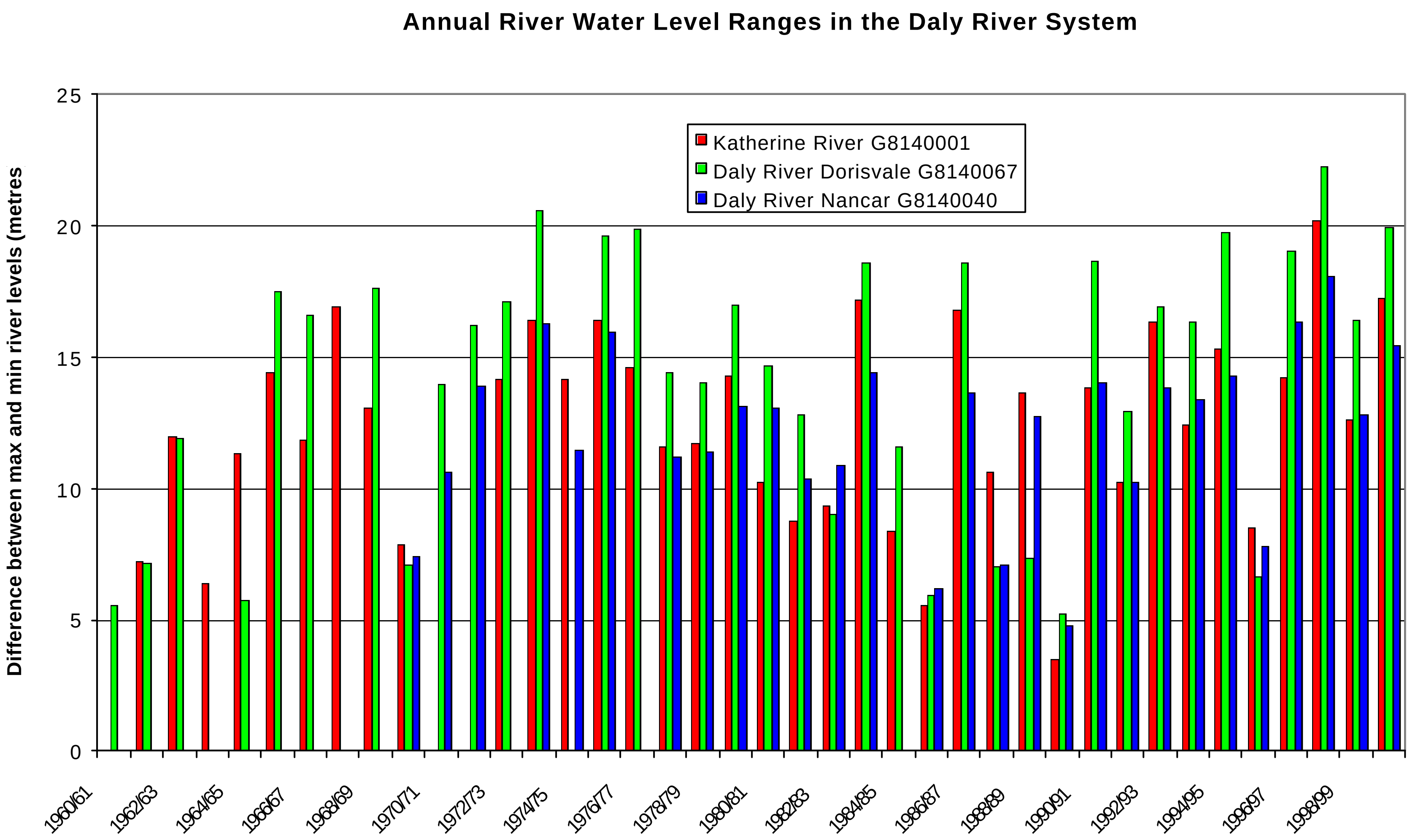


Figure 9. Variation between Annual Highest and Lowest River Water Level for G8140001, G8140067 and G8140040

Note: Where no data is shown for a station for a year, it indicates that inadequate data exists to define data point.

5.3 Discussion on Regional Groundwater Discharge

The majority of this discussion will focus on the regional groundwater discharges from aquifers developed in the carbonate strata of the Daly Basin (shown in green on the accompanying map) and Cretaceous sandstones (shown in blue on Figure 1).

Smaller springs occur throughout the region. Some have a small flow (<10 litres per second) throughout the year. Most cease to flow early in the dry season. These springs drain a very small area (less than 1 square kilometres) and, while they may be ecologically significant, are outside the scope of this discussion.

Data on instantaneous flow rates for various locations in the Daly River Catchment at the end of the “dry season” are given in Table 7. This data represents flows at these locations after a series of below average, average and above average wet seasons. These flows are sustained by significant regional groundwater discharges.

Table 7. Gauged Flows at Various Locations in Oct/Nov 1970, 1982 and 2000

River or Creek	Gauging Station	Flow October 1970 “below average” (cumecs)	Flow October 1982 “average” (cumecs)	Flow October 2000 “above average” (cumecs)
Seventeen Mile Creek	G8140159	0.2	0.4	0.5
Katherine River - Low Level Crossing	G8140001	0.9	1.9	2.9
Katherine River - Galloping Jacks	G8140301	1.0*	2.3	3.4
Flora River	G8140044	3.4*	3.4*	3.7
Daly River -Dorisvale Crossing	G8140067	2.8	5.1	8.5
Daly River near Stray Creek		5.2	9.9	15.2
Daly R downstream of junction with Jinduckin Creek				20.8
Daly River - Oolloo Crossing		5.9	13	20.8
Douglas River	G8140063	0.3	0.7	1.2
Douglas River above junction with Daly R				3.3
Daly above junction with Douglas R				21*
Daly River - Nancar	G8140040	8.5	19.4	24*

Note: * indicates estimated value

The data contained in the above table has been used on the map accompanying this report to identify those stretches of the rivers and creeks of the Daly River catchment that have strong regional groundwater discharges into them.
More detailed discussion on regional groundwater discharges from aquifers developed in the Cretaceous sandstones and carbonate strata of the Daly Basin follows.

5.3.1 Cretaceous Sandstones

Regional groundwater discharges from these sandstones provide the dry season flow for Seventeen Mile Creek. This Creek maintains the water level in the first pool in Katherine Gorge and provides the source of most of Katherine’s water supply via Donkey Camp pool. The minimum instantaneous flow rates have varied between 0.15 and 1 cumec since 1960 (refer Figure10)

These changes in minimum flow rates occur in response to changes in the amount of rainfall that recharges the aquifer each year. The changing recharge rate is reflected in the variation in water level measured in a monitoring bore intersecting the aquifer. Figure 11 is a plot of data for bore RN22747 which is located near Maranboy. The data indicates that annual recharge rates vary from 0 to about 150 mm. The mean for the period would be about 40 to 60 mm. Low water levels correspond to the period when flows were at their lowest at G8140159, higher water levels to higher flows.

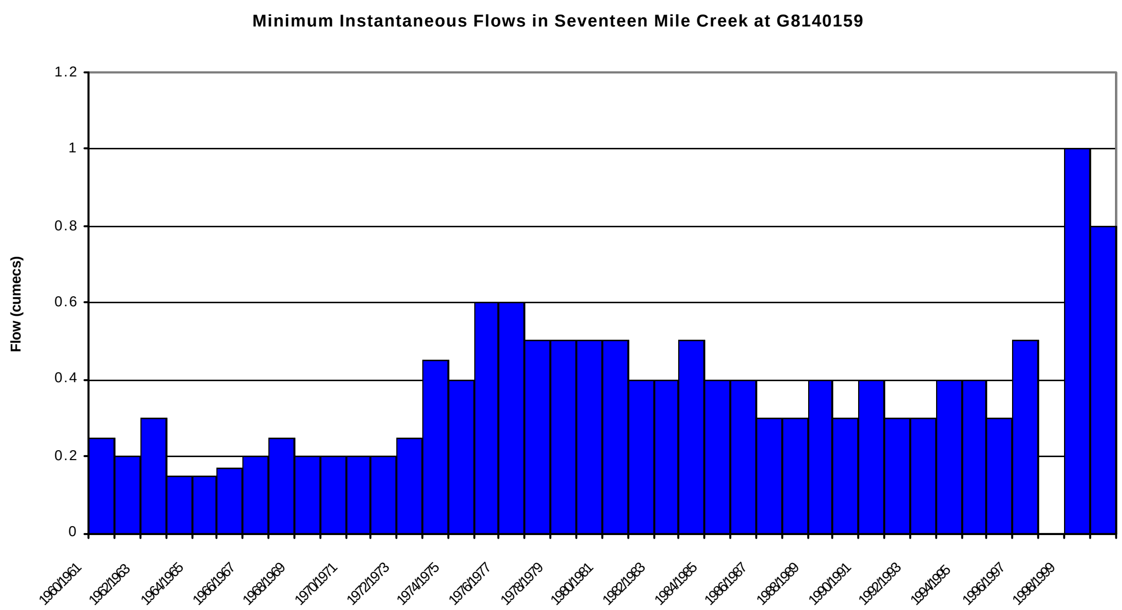


Figure 10. Minimum Instantaneous Flows at Seventeen Mile Creek G8140159

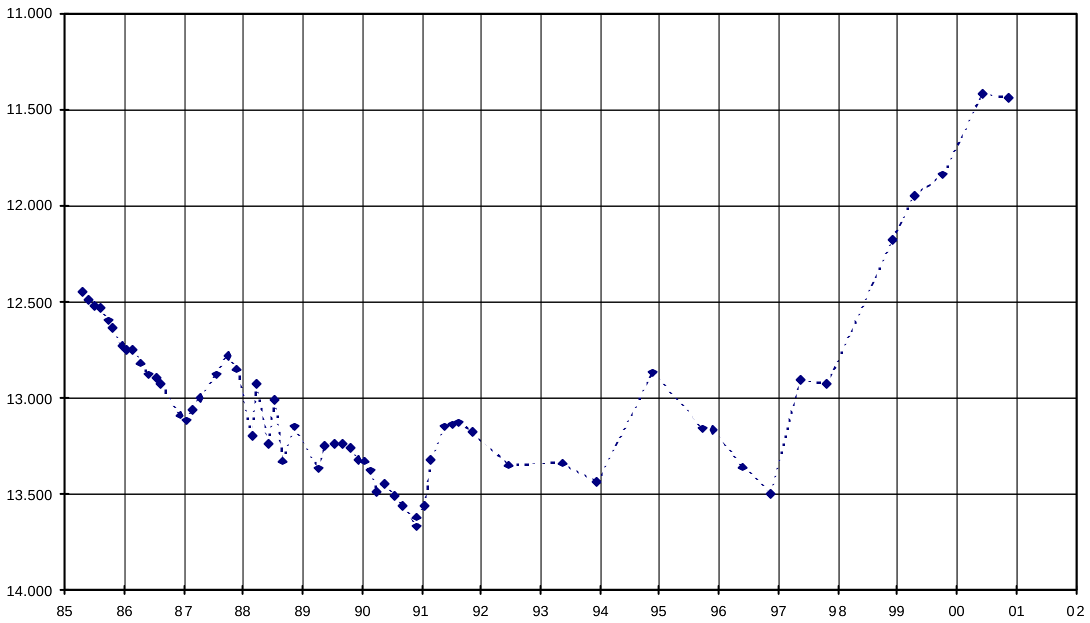


Figure 11. Data on Water Levels in Bore RN22747 in Cretaceous Sandstone

5.3.2 Carbonate Sediments of the Daly Basin

Regional aquifers developed in the Tindall Limestone are the source of large dry season inflows into the Katherine, Flora and Douglas Rivers (near G8140063). It is also probable that the Tindall Limestone provides significant input into the Daly River upstream of its intersection with Bamboo Creek. However, no reliable data for dry season flows exists for this stretch of the Daly River.

Regional aquifers developed in the Oolloo Limestone are the source of large dry season inflows into the Daly and Douglas Rivers. The general locations of the most significant inflows are given in Figure 1. The best data on regional groundwater discharges from the carbonate sediments exists for G8140001 on the Katherine River, and G8140040 and G8140067 on the Daly River. The dry season flow data for G8140044 and G8140063 is not as good. Analysis will therefore be confined in this overview to data from G8140001, G8140040 and G8140067.

Regional groundwater discharges are maintained by recharge into the regional aquifer systems that has occurred over the preceding wet season or wet seasons. This recharge results in water levels rising in the aquifers. The magnitude of the water level rise can be used to estimate the quantity of recharge.

Data is given in Figures 12 and 13 for two bores in the Douglas – Claravale area that monitor water levels in the Oolloo Limestone. At the site given in Figure 12 the Oolloo Limestone outcrops. At the site given in Figure 13 the Oolloo Limestone is overlain by Cretaceous Sandstone. Where the Oolloo Limestone outcrops annual rises of up to 8 metres occur with water levels falling about 2 metres a year. Where it is covered by Cretaceous Sandstone annual rises of up to 2 metres occur, with levels falling about 0.5 metres per year. This indicates that about four times as much water is recharging and discharging from the aquifer where the Oolloo Limestone outcrops. The extent of the Cretaceous cover has not yet been areally determined. The mean annual recharge rate for the period shown has been determined to be approximately 150 mm where the Oolloo Limestone outcrops and about 40 mm where it is covered by Cretaceous Sandstone. The mean areal recharge rate for the Oolloo Limestone between Claravale and the Douglas River has been estimated by Jolly (83) to be 100 mm. This would indicate that Cretaceous Sandstone covers about 50% of the Oolloo Limestone in this area,

Data is given in Figures 14 and 15 for two bores in the Katherine area. At the site given in Figure 14 the Tindall Limestone outcrops. At the site given in Figure 15 the Tindall Limestone is overlain by Cretaceous Sandstone. Where the Tindall Limestone outcrops annual rises of up to 7 metres occur with water levels falling about 5 metres a year after above average wet seasons, and about 0.7 metres after below average wet seasons. Where it is covered by Cretaceous Sandstone annual rises of up to 3 metres occur, with levels falling about 0.7 metres per year. This indicates that about twice as much water is recharging and discharging from the aquifer where the Tindall Limestone outcrops. The extent of the Cretaceous cover has not yet been areally determined. The mean annual recharge rate for the period shown has been estimated to be about 50 mm where the Tindall Limestone is covered by Cretaceous Sandstone and approximately 100 mm where the Tindall Limestone outcrops. The mean areal recharge rate for the Tindall Limestone in the Douglas River area has been estimated by Jolly (83) to be about 100 mm. In the Douglas River area there is no Cretaceous Sandstone covering the Tindall Limestone.

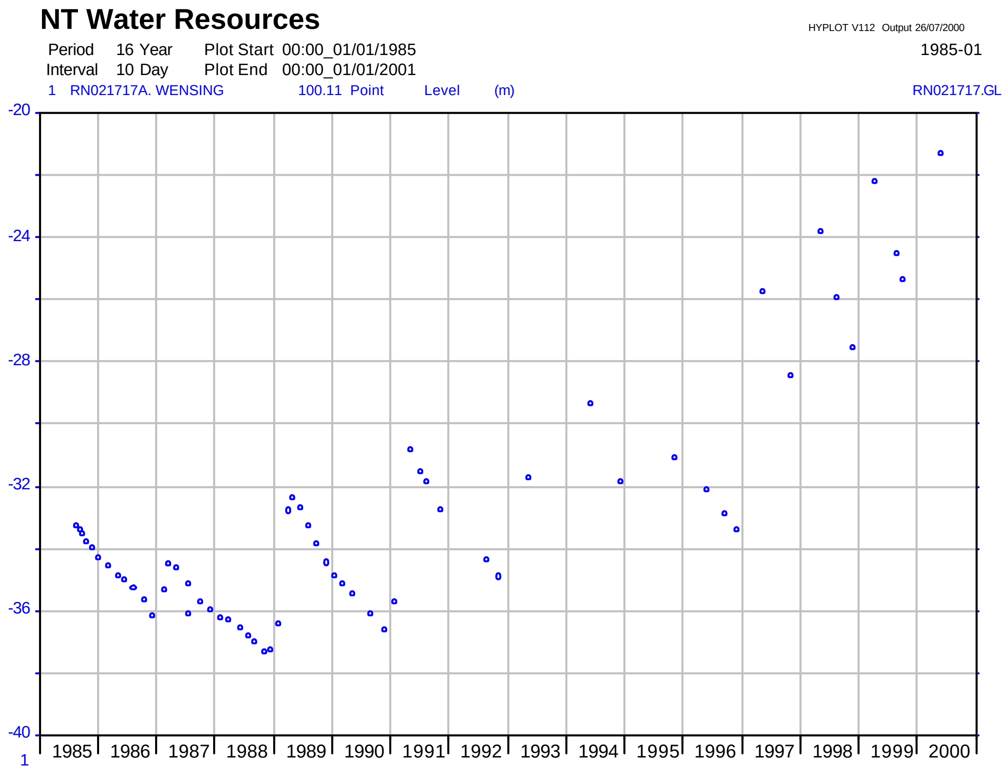


Figure 12. Water Level for Aquifer in Oolloo Limestone (Limestone outcrops)

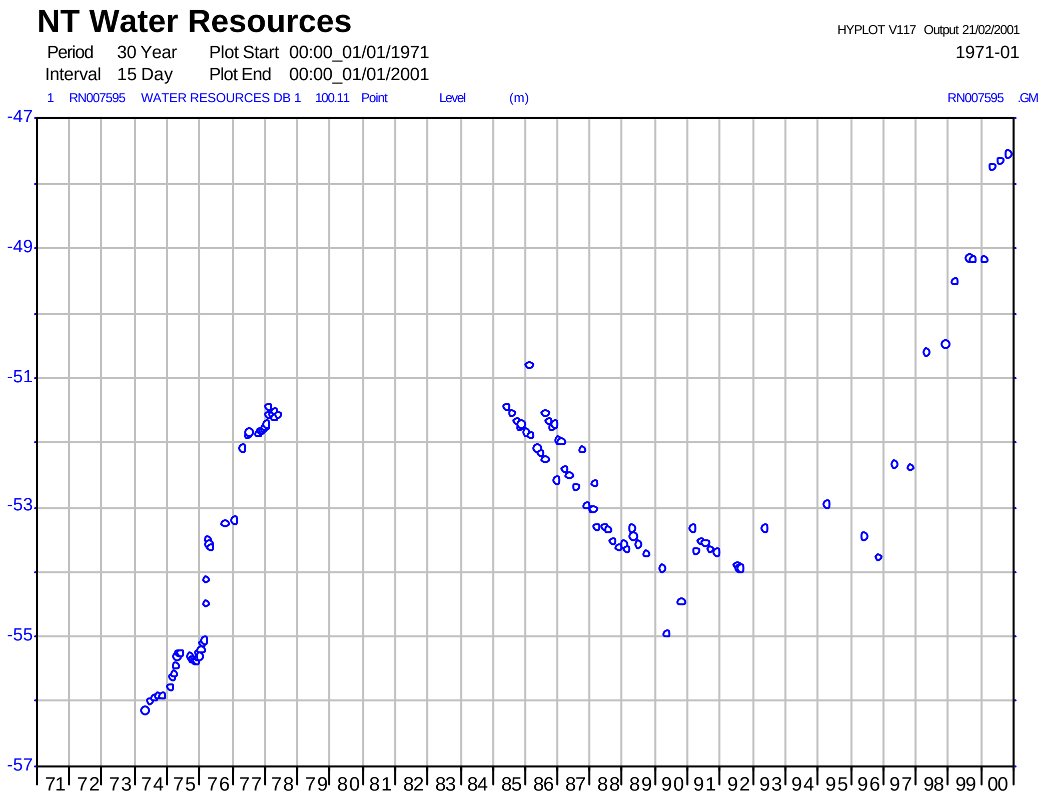


Figure 13. Water Level for Aquifer in Oolloo Limestone (Cretaceous cover)

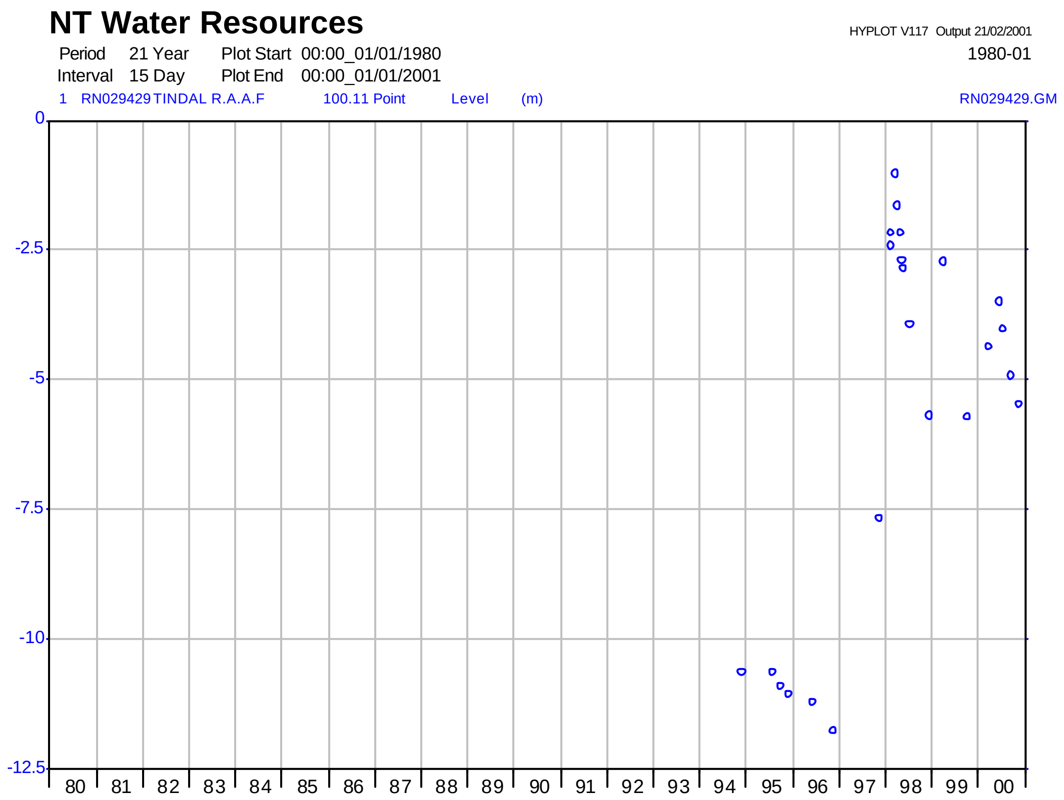


Figure 14. Water Level for Aquifer in Tindall Limestone (Limestone outcrops)

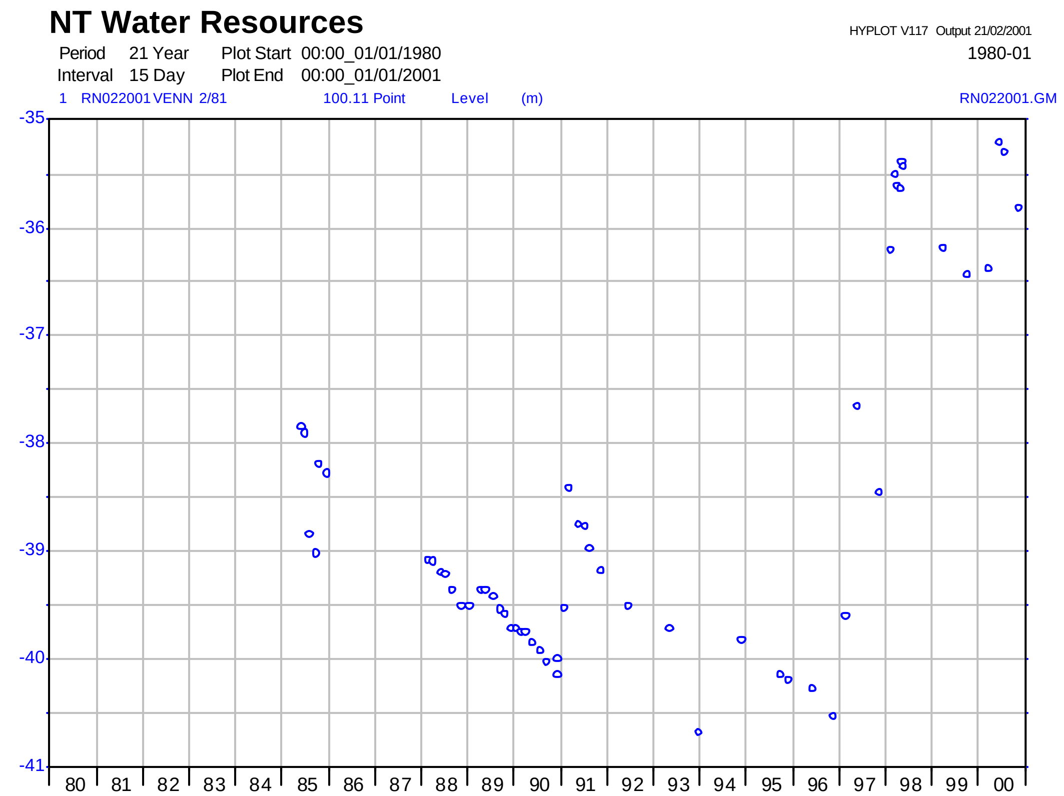


Figure 15. Water Level for Aquifer in Tindall Limestone (Cretaceous cover)

The amount of recharge to an aquifer system can also be determined from data on dry season flows. Minimum instantaneous flow data for each year for which adequate records exist have been plotted on Figure 16 for the three stations G8140001, G8140040 and G8140067. Detailed analysis has only been attempted for G8140001. This work was reported on by Jolly (2000). That work also identified that a linear relationship existed between regional groundwater discharges at G8140001 and those at G8140301. Discharges as measured at G8140301 are 17% greater than at G8140001. Discharges measured at G8140301 represent the total outflow from the aquifer in the Tindall Limestone in the Katherine area into the Katherine River. This data was then used to predict regional groundwater discharges at G8140301 for the full period of Katherine's rainfall record (Jolly 2000). The predicted discharges are plotted on Figure 16 along with actual discharges (either gauged or predicted from the flow record at G8140001). The underestimation of the higher flow values has probably occurred because in those years river flow at the end of the dry was likely still being influenced by groundwater discharge from offstream bank and aquifer storage.

Based on the predicted minimum flows for G8140301 for the period 1884/85 to 1999/2000, and assuming that the mean annual regional groundwater discharge rate is 10% greater than the minimum yearly value, the mean annual regional groundwater discharge rate for the period 1884/85 to 1999/2000 is approximately 1.6 cubic metres per second. This equates to a mean annual recharge rate of 90 mm for the period.

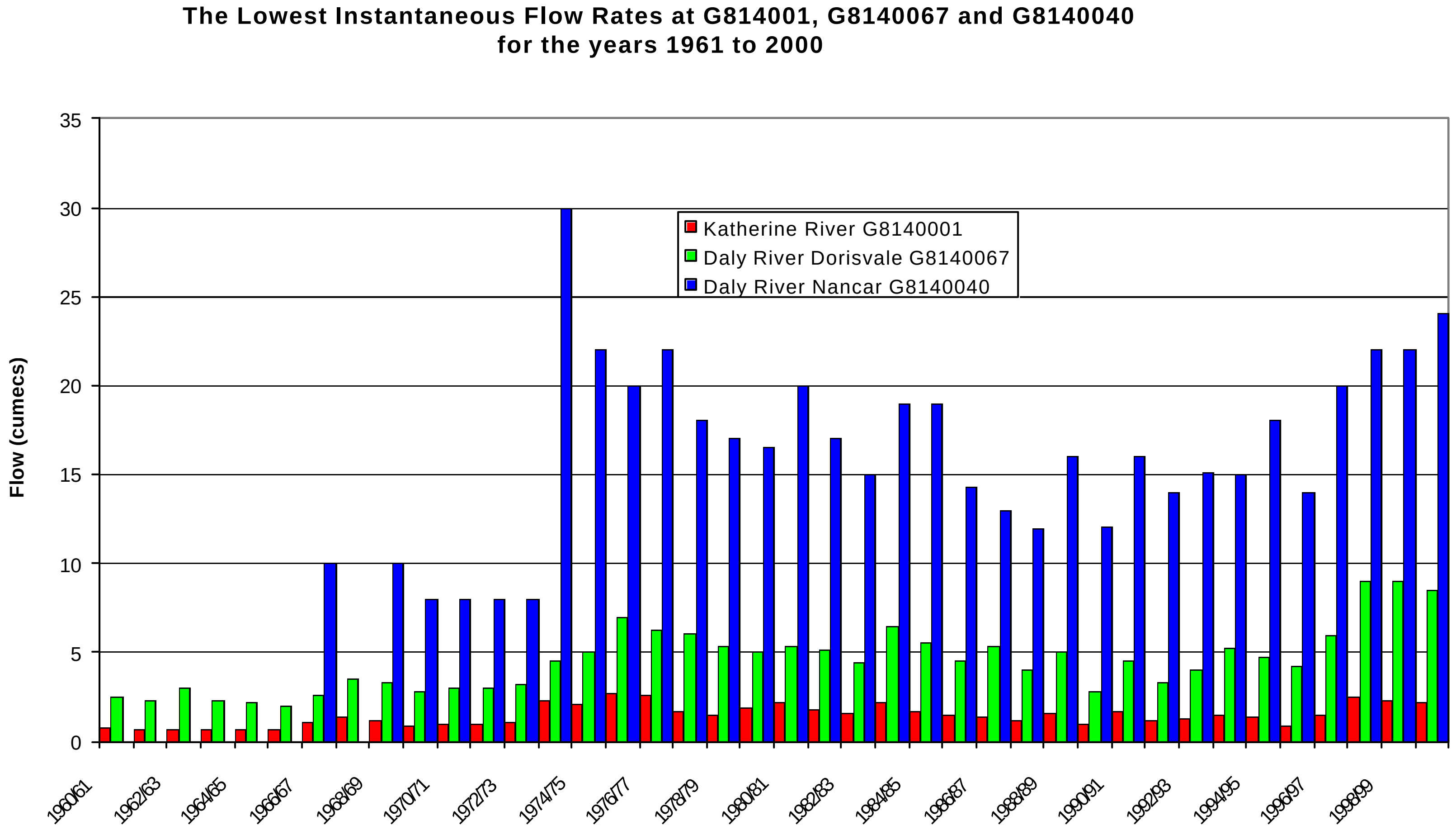
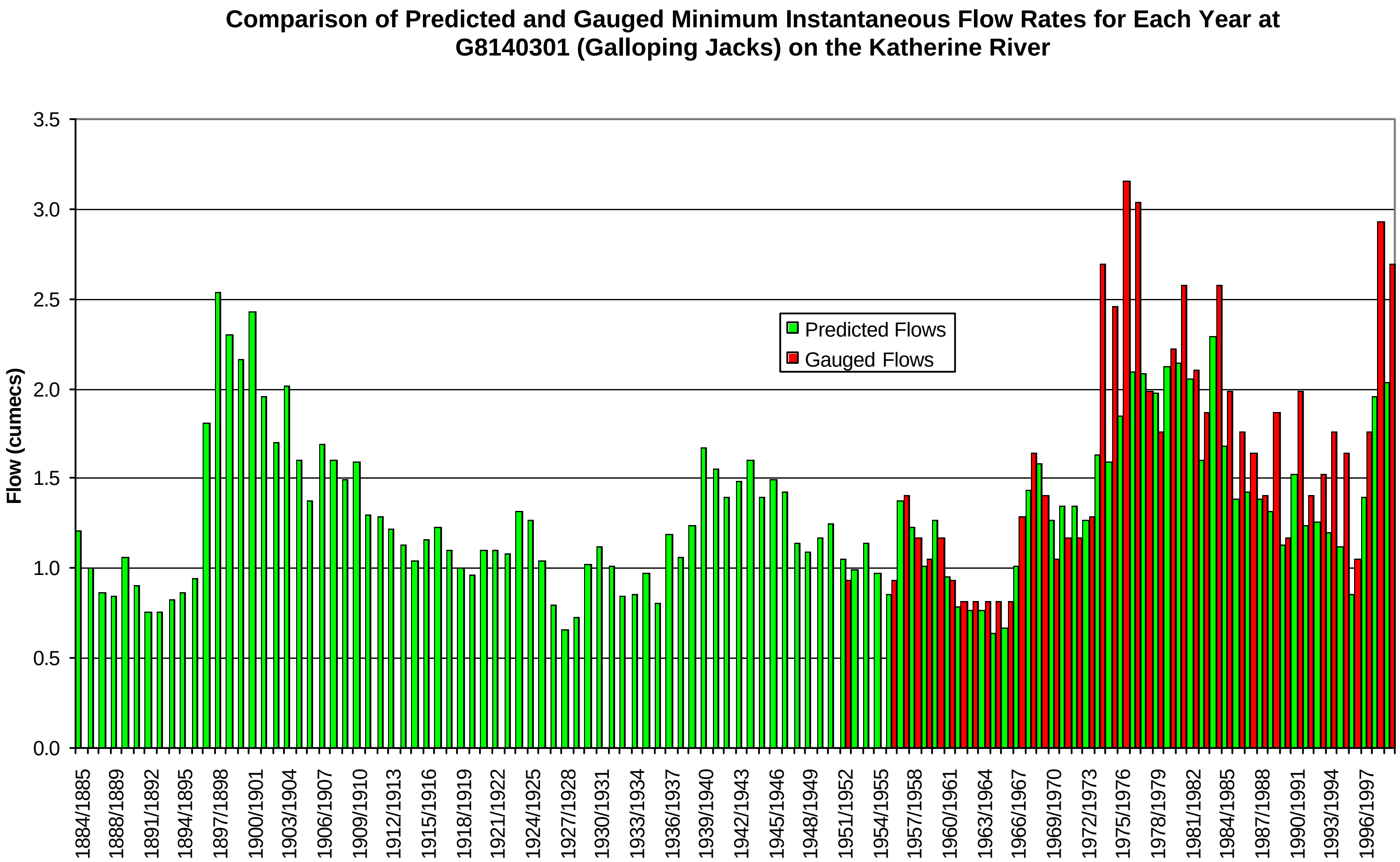


Figure 16. Minimum Yearly Flow Rates for Katherine River at G8140001 and Daly River at G8140067 and G8140040

Note: Where no data is shown for a station for a year, it indicates that inadequate data exists to define data point.

Figure 17. Predicted Minimum Annual Flows at G8140301 derived from gauged data at G8140301 and G8140001



6. Evapotranspiration

Evapotranspiration occurs from the trees, understorey and the ground surface. Data acquired by Hutley et al (2001) suggests total evapotranspiration during the wet season for the Katherine area is 3.1 mm per day. Annual tree water use was estimated to be approximately 150 mm. Wet season pan evaporation rates averaged about 5.5 mm per day.

Jolly (2000) trialed a range of values for evapotranspiration for the recharge area for the Tindall Limestone aquifer in developing a model to predict historical groundwater fed flows in the Katherine River. A value of 150 mm was used for the maximum soil moisture deficit (difference between saturated and free draining moisture content of the profile above the water table) during development of the model. A range of values was trialed for wet season daily losses (primarily due to evapotranspiration). A value of 5mm per day was chosen in the model as it yielded the best correlation between gauged and predicted groundwater fed river flows. Use of these values yielded a predicted mean annual potential recharge rate of 225 mm. This is considerably higher than the 90 mm estimated from the flow record. This difference is due to runoff being included in the figure derived for the potential recharge rate. No data exists for mean annual surface water runoff from the ground overlying the Tindall Limestone in the Katherine area. However, the mean annual surface water runoff from the Daly River Catchment is approximately 135 mm. If this figure was subtracted from the predicted mean annual potential recharge rate, the value for the mean annual recharge would be 90 mm. More work, however, is required to refine the baseflow synthesis developed for G8140001 and G8140301 in Report 36/2000D, with that work initially focusing on quantifying the runoff component of the potential annual recharge.

Zaar et al (three reports - dates?) reported late dry season losses in flow rate in the Katherine and South Alligator Rivers ranging between 2.9 and 5 litres per second per kilometre length of river. The higher (5 litres per second per km) calculations were made over stretches of the Katherine and South Alligator Rivers where groundwater inflow from and outflow to the river was deemed to be negligible due to the rivers incising very low permeability strata. The lower value (2.9 litre per second per km) was calculated over a stretch of the Katherine River where the river was likely to be gaining a small amount of inflow from the limestone strata the river was incised into.

These losses in flow rate were attributed to evaporation losses from the rivers and transpiration from their riparian zones.

In Table 8 an attempt has been made to evaluate the amount of water that is evapotranspired from creeks / rivers / wetlands and their riparian zones. An allowance has to be made for additions to, or losses from groundwater storage. However, the data contained in the table indicates the variability in the amount available each year.

Table 8 Evapotranspiration from creeks, rivers and wetlands of the Daly River Catchment

Components of Groundwater Balance	**Annual Amounts for Catchment (mm)**		
	Minimum	**Maximum**	**Mean**
Rainfall (DR014902, 1957 – 2000)	500	1620	970
Recharge (1957 – 2000)	0	300	90
Inflow from adjacent aquifers	0.8	1.5	1
Groundwater outflow as measured at G8140040 on the Daly River	6	25	13
ET from creeks / rivers / wetlands and their riparian zones and water added / taken from storage	?	276.5	78

7. Groundwater and surface water extraction

The National Land and Water Audit Theme 1 study has estimated usage figures for the Katherine Water District (refer Figure ?). This area covers parts of the Oolloo Limestone, as well as the Tindall Limestone. Their estimate of usage is approximately 16000 ML/year (ie 44 ML/d). The predicted use in 2020 and 2050 is 80000 ML/year (220ML/d) and 120000 ML/year (330ML/d), respectively.

No figures exist for the amount of water currently being used in the Katherine / King River area which is sourced from the aquifer in the Tindall Limestone. However, based on a water usage of 10 ML/ha/year for irrigation, and using existing satellite images, and the author's estimates for private and public water supply use, the current usage of groundwater sourced from the Tindall Limestone (either from bores or river baseflow) is approximately 9000 ML/year (or 25 ML/d). This figure is consistent with the figure being used in the NLWA Theme 1 study. It is probable that peak daily usage currently would approach 50 ML/d in the August – September period.

The following data exists for licensed surface water allocations in the Daly River catchment:

1. For Katherine, the annual allocation is 7569 megalitres. Of this amount, 4500 megalitres is allocated to PAWA for use in Katherine's water supply system.
2. For the rest of the Daly River catchment annual allocations total 1180 megalitres.

Unlicensed water usage (riparian and groundwater) for the rest of the Daly River catchment would be about 1000 megalitres per year.

There are only two small weirs used for water supply purposes in the Daly River catchment. Both storages are very small. The weir at Donkey Camp on the Katherine River (Katherine water supply source) provides an additional storage of about 1500 megalitres when full. The small weir on a tributary of Copperfield Creek (Pine Creek water supply source) has a storage capacity of less than 100 megalitres.

8. Water stored above and below water table

No detailed work has been undertaken to quantify either of these parameters. Therefore the following estimate has been based on the author's extensive knowledge of the study area.

The amount of water stored above the water table varies according to the type of strata and the season. All strata in the catchment have negligible primary porosity except where they have been extremely weathered. Based on data from boreholes drilled in the catchment it is probable that the average depth of this extremely weathered zone averages about 20 metres. In most aquifers in the study area seasonal water table fluctuations occur in this zone. However the change from unsaturated to saturated conditions usually results from the addition of only a small amount of water (up to 5% by volume) due to the clayey nature of most of the extremely weathered strata. The average water content of this 20 metre zone would be expected to be about 25 % by volume.

The porosity, and hence water content, of the strata below 20 metres is dependent on the amount of weathered fractures or voids. The occurrence of these weathered fractures or voids is dependent on the composition of the strata they occur in. The consistent factor for each type of strata is that the number of weathered fractures or voids decreases with depth. Averaged over the catchment, weathered fractures or voids would occupy about 2% by volume of the strata above 100 metres depth and negligible amounts below 100 metres.

Based on the above assumptions, the following estimates have been derived for the amounts of water stored in the various parts of the profile over the 52,600 square kilometres of the Daly River catchment:

1. Volume of water stored above and below the water table - 350 x 10^6 megalitres.
2. Volume of free draining water stored in the extremely weathered zone - 50 x 10^6 megalitres.
3. Volume of adsorbed water stored in the extremely weathered zone - 220 x 10^6 megalitres.
4. Volume of free draining water stored in the weathered zone - 80 x 10^6 megalitres.
5. Average volume of water added as recharge each year - 5 x 10^6 megalitres.

9. Water Balance Summary

The following table provides an overview of the water balance for Daly River Catchment (based on Katherine rainfall and runoff data) for the major components of the water balance in the Daly River catchment

Table 9 Water Balance Summary

Components of Water Balance	Annual Amounts for Catchment (mm)		
	Minimum	Maximum	Mean
Rainfall (DR014902, period 1957 – 2000)	500	1620	970
Runoff (G8140001, period 1957 – 2000)	50	590	220
Recharge (period 1957 – 2000)	0	300	90
Transpiration by large trees	150	150	150
Understorey Evapotranspiration	300	580	510
Inflow from adjacent aquifers			1
Water stored above and below water table	6500	6600	6550
Pumping for water supply purposes			0.4

The main hydrologic characteristic of this catchment is the great variability in rainfall from year to year, within a single year and over periods of years. This variability results in a similar great variability in both surface water runoff and groundwater recharge.

The period of record for most gauging stations and groundwater monitoring points within the catchment is biased towards a period of above average rainfall (based on the existing rainfall data). This needs to be taken into consideration when analysing flow and recharge data. This is the primary reason for the work undertaken to synthesise the historical regional groundwater discharge record for discharge from the aquifer in the Tindall Limestone into the Katherine River (refer Figure 16).

The catchment is still largely undeveloped. Prior to further significant development of the water resources occurring a sounder understanding is required of the interaction between the regional aquifers and those sections of rivers identified on the accompanying map as being sections into which a significant amount of groundwater discharges.

There is also a need to undertake a preliminary analysis of the hydrological data that exists for the various parts of the catchment. This analysis is required to identify the type of hydrological data that the Government needs to collect to underpin the sustainable development of the Daly River catchment.

10. Recommended Work

1) Determine the reason for the apparent increase in dry season flow at GS8140044 on the Flora River and re-evaluate existing flow data
2) Undertake groundwater resource investigation of the Oolloo Limestone to better define recharge / discharge characteristics
3) Develop regional groundwater flow models for aquifers developed in the Tindall Limestone and Oolloo Limestone in the Daly Basin.
4) Refine the baseflow synthesis developed for G8140001 and G8140301 in Report 36/2000D. This refinement should initially focus on quantifying runoff for the various times of the wet season.
5) Undertaking similar exercises for groundwater fed flows at gauging stations GS8140044, GS8140063, GS8140067 and GS8140040.
6) Further develop the relationship between near river recharge to aquifers during the wet season, and subsequent discharge to the Katherine River and Daly Rivers.
7) More precisely identify major groundwater inputs into the Daly River.
8) Develop runoff and small dam design criteria for small catchments in close proximity to soils suitable for irrigated agriculture.
9) Undertake an overview study of the Daly River coastal floodplain to identify work required to better understand hydrological processes and management responses required.
10) Undertake a preliminary assessment of significant issues and work required to assess the feasibility of large dams in the Daly River catchment.
11) Evaluate the impact of clearing trees on the water balance in the Douglas River – Stray Creek area.

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