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Executive Summary

According to records available from gauging stations operated by DNR, 29% of total river flow in the Balonne River at St George is lost before reaching stations near the Qld-NSW border. During major floods the percentage lost is even higher. Downstream of St George the terrain is very flat. The river bifurcates and flows are distributed between several streams or distributaries. Significantly, the channel capacities of these distributary streams are relatively small and much of the flow is conveyed as overbank flow or floodplain flow. Satellite imagery vividly displays the dispersion of flow and the broad extent of inundation which occurs during floods.

As a consequence of the extensive floodplain flow, an unusually large percentage of flow at the five stations near the NSW border occurs as overbank flow. At most stations, a large percentage of flow also occurs when the river levels exceed the range of discharge measurement. When flows exceed bank-full levels it becomes very difficult to measure discharge, and when flows exceed the range of discharge measurement the discharge must be estimated by extrapolating the observed relationship between stage (river level) and discharge.

Due to the amount of overbank flow which occurs, the accuracy of the "recorded" discharge at the lower stations has been questioned. This judgment has been recognised previously in a report undertaken by Department of Primary Industries (DPI, 1983) in which it was concluded that “further gauging at high flow levels are required on the Culgoa River in Queensland and on all streams in NSW so that the models will more adequately simulate the patterns of water distribution”.

For the purposes of this study data was obtained from DNR and the discharge ratings were discussed with DNR hydrographers. Low accuracy of estimation of medium to high flows appeared likely, raising the potential for significant error. In particular, at none of the five lower stations does survey of cross-sections extend more than a few hundred metres, and yet in floods, flow at these stations often develops several kilometres wide.

To evaluate the potential for error, satellite imagery obtained over the last 20 years was used to estimate the extended cross-section which develops during floods. The width of flow on the imagery was related to the maximum stage which occurred at each of the stations at

the time. As the images rarely coincide precisely with maximum stage, the width of the cross-sections and hence the cross-sectional area available for flow is, if anything, underestimated. By this means a greatly extended cross-section was estimated which includes virtually the full range of flow.

Discharge is the product of velocity and cross-section area. Velocities within the channel part of the cross-section are available within the range of field measurements of discharge. The relationship between velocity and river stage can validly be extrapolated, but it applies only to the channel part of the cross-section. Channel flows at high stage were estimated by extrapolating the velocity stage relationship and the channel cross-section. During floods at these stations however, a very large part of the flow is conveyed in the overbank part of the cross-section. Much lower velocities occur in overbank flow, particularly in shallow overbank flow with vegetation resistance.

The velocity of overbank flow had to be estimated, mainly from professional experience, but also supported by unofficial observations of flow velocities in the floodplain and hydraulic computations. Due to the inherent uncertainties in velocity estimations, different values of overbank flow velocity were assumed, consistent with experience, anecdotal evidence and simple hydraulic formulae. A range of 0.075 m/s to 0.15 m/s was assumed. Based on these assumptions extrapolations of the rating between stage and discharge were calculated. Even with the lowest assumed velocity of 0.075 m/s, the total volume of flow for the five lower stations near Hebel exceeds the volume based on official records by 15%.

Although the data used in the analysis involves approximations and the analysis is preliminary, the findings imply that the official records under-estimate the volumes of flow across the floodplain because they make inadequate allowance for the overbank flow which occurs on a large scale during floods. The estimate of 15 % low is believed to be conservative. The difference between "recorded" and actual flows could easily be greater, up to 30 % or more. Even with the assumption that flows may be under-estimated by 15 % in the long term (if velocity of overbank flow is 0.075 m/s), the difference varies between years and the difference is estimated to be up to 25 % in years of high flood.

Table 1 gives a summary of the results assuming overbank flow velocity of 0.075 m/s.

Table 1

Station Number	Stream	Total Flow (GL) from DNR records 1968 - 1987	Total Flow (GL) estimated by SKM 1968 - 1987	Percentage difference
422 206A	Narran	4 947	4 860	-2%
422 209A	Bokhara	1 608	1 483	-8%
422 207A	Ballandool	1 581	1 581	0
422 211A	Briarie Ck	1 890	2 658	+41%
422 208A	Culgoa	8 072	10 183	+26%
sum of above	Combined Lwr Balonne	18 099	20 766	+15%
422 201A	D/s St George	25 638		
Loss from St George to near Hebel:		29%	19%	

This alternative data set also gives a total loss of flow between St George and Hebel of 19 % as compared with 29 % as stated by DNR. It could well be less.

The implications of this finding are important in several respects. For example, preliminary results of IQQM modelling undertaken for development of the Condamine-Balonne WAMP presented to the CRP indicate that flows crossing the NSW border under full development of existing licences would be roughly 50 % of the natural or pre-development flows. If the data upon which this is based is underestimated by 15 %, a more appropriate value would be roughly 58 % of natural.

1. Background

1.1 Study Objectives

This study arises from a request from the Dirranbandi District Irrigators Association and the St George Water Harvesters Association to examine the hydrology of the Lower Balonne.

Downstream of St George near Whyenbah the Balonne River begins to separate into several distinct streams or distributaries. These distributaries disperse flow over an ever wider floodplain as the river flows south-west towards the Barwon and Darling Rivers in NSW. The distributaries include the Narran, Bokhara, Ballandool and Culgoa Rivers. The Narran terminates in a lake in northern NSW. Another feature, Briarie Creek, acts as a collector or concentrator of floodplain flow and only functions during floods.

During periods of small to moderate discharge the flows are wholly or largely contained within the distinct waterways. During large discharge events flows break out into the floodplain and depending on the flood magnitude the extent of flooding can be very widespread (see, for example, interpretations of flood extent from satellite imagery in DPI, 1995).

The wide extent of overland flows in the region makes estimation of river flows during floods quite difficult, particularly further downstream where a series of gauges operate just upstream of the NSW border. Some sites are difficult to access during floods. It appears from anecdotal advice that only at the one station on the Narran River (at Dirranbandi – Hebel Road) has measurement of overbank flow been attempted. In extrapolation of discharge ratings at other sites inadequate allowance may have been made for the magnitude of overbank flow which can develop during floods.

The primary objective of this study was to investigate the potential inaccuracy which may have been introduced in extrapolations of discharge ratings.

This is important for at least two reasons:

(1) Estimation of the losses which occur between St George and the NSW border, which is in turn used in determining appropriate water allocations for irrigators and water harvesters.

(2) Estimation of the flows which cross the border into NSW, which in turn is used to assess water

consumption in Queensland and its effects on river flows and the river and riparian environment.

1.2 Study Approach

The discharge ratings and flow records were discussed with DNR Hydrographic staff in Toowoomba and Brisbane, and records were obtained from eight stations downstream of St George. In general, records with continuous recorders commenced *c*.1967, and except for the station on the Culgoa at Woolerbilla which was closed in 1988, all still operate. Few of the stations in far northern NSW have records from continuous recorders so it was considered that acquisition of those records would not contribute to the accuracy of the analysis.

Limited topographic data was obtained through the Dirranbandi District Irrigators Association. More topographic data and flow distribution data was sought from consultants Connell Wagner who have undertaken hydraulic modelling with the Rubicon model, but this data did not arrive in time for use in the analysis reported here.

Published interpretations of satellite imagery from several floods was available (DPI, 1995). More recent satellite imagery was also available from consultants SMEC (UC, 1999), who are also undertaking hydraulic modelling in current development of a Floodplain Management Plan for the Lower Balonne.

Cross-section data was examined to estimate the river stage at which flows ceased to be contained within the banks. Flow records were then analysed to determine the percentage of time that stage exceeded these limits and the percentage of flow which was contained within those intervals when overbank flow occurred. This confirmed that high percentages of total flow occurred during these intervals.

Examination of the discharge ratings where they were extrapolated beyond the range of gauged flows justified the concern that they may not adequately account for overbank flow. The precise means by which discharge ratings were extrapolated has not been determined, but it seems likely that this was achieved either through extrapolations of the cross-section areas and mean velocities of flow or by graphical means. Neither of these methods would properly account for the magnitude

of overbank flow. The first method has the potential to do so, except that only small widths of the total cross-section available to flood flow have been surveyed.

Although good topographic data to extend the cross-sections was unavailable, the approximate width of flow at each of the stations was estimated from the flood extents in historical floods interpreted from satellite imagery. This enabled extended cross-sections to be approximated. In future floods, new generations of satellite technology will permit greater accuracy in the determination of flood extents.

Unofficial observations of overland flow velocities enabled a rough estimate of overbank flow rates to be made. Given the relatively low reliability of these observations and the assumption of their more general applicability in the floodplains, sensitivity analysis was undertaken. For inbank flow (*i.e.* flow within the banks), the extrapolation of measured mean velocity was used.

Based on the estimated inbank flow plus the estimated overbank flow cross-section and assumed velocities of overbank flow, alternative discharge ratings were devised for the high flow range. These were then used to convert records of observed stage at the gauging stations to records of estimated discharge.

The estimated discharges were then used to undertake a water balance between upstream and downstream stations and to compare the volumes of flow estimated by DNR (*i.e.* the official flow records) and the volumes of flow estimated in this study.

2. Hydrology

2.1 Data Collection

Eight stream gauging stations are located in the study area. These stations are described in **Table 2.1** and shown on **Figure 2.1 – Locality Plan**. The period of record at these stations varies however all stations had commenced recording by July 1967 and most stations continue to record data to the present date. The shortest period of record is at Woolerbilla on the Culgoa River which ceased recording in 1988 after 23 years.

Table 2.1: Stream Gauging Stations in Study Area

Gauging Station Number	Location	Period of Record	Catchment Area (km^2)
422 201D 422 201E	Balonne River at St George	01/10/66 – 04/08/71 01/10/71 – present	75 370
422 204A	Culgoa River at Whyenbah	31/07/65 – present	79 330
422 205A	Balonne-minor River at Hastings	05/08/65 - present	79 330
422 206A	Narran River at Dirranbandi-Hebel Road	01/08/65 - present	80 110
422 207A	Ballandool River at Hebel-Bollon Road	01/08/65 – present	80 185
422 208A	Culgoa River at Woolerbilla	30/07/65 – 30/09/88	80 405
422 209A	Bokhara River at Hebel	01/08/65 – present	80 030
422 211A	Briarie Creek at Woolerbilla-Hebel Road	18/07/67 – present	410

The data associated with each of these stations was purchased from the Department of Natural Resources. This data included:

- Site Summary Report – detailing the site description, station description, station history, rating table summary, cross section data and period of record.
- Rating Tables and the period of applicability
- Monthly summaries
- Measured stream cross section at the gauge
- Daily recorded stage
- Daily discharge – determined from the rating table

Other items of data were also received:

- Report on *The Compilation of Regional Flood Maps using Remote Sensing Techniques over the Balonne River Catchment and Downstream Areas*, Department of Primary Industries, August 1995.
- Topographic Map SH 55-3 Dirranbandi, 1:250,000 scale.

- CD containing plans and drawings from the Lower Balonne floodplain studies, courtesy of Connell Wagner.
- Information on peak flood levels and estimated flow velocities during floods of September 1998 and March 1999 in Cubbie Station floodways and at the diversion weir on the Culgoa River at Cubbie Station.
- Report on *Large Scale Habitat Mapping of the Lower Balonne Floodplain*, Sims/Thoms/Ogden, University of Canberra, 1999 and associated mapping on CD.
- Report on Unregulated Flow Studies for the Condamine/Balonne/Culgoa River System, *Hydrologic Modelling of the Balonne Distributary System Downstream of St George, Volume 1: Main Report*, for Dumaresq-Barwon Border Rivers Commission, Water Resources Department of Primary Industries, Queensland, March 1983

2.2 Potential Effect of Overbank Flow

As a first step, the importance of overbank flow at the five stations near the NSW border was evaluated. From the surveyed cross-sections at each of the stations, the river stage at which flow would no longer be confined within the banks was estimated.

For most stations the survey extended over a few hundred metres and an appropriate level could be determined. Even so, there is a possibility that breakouts could occur at a lower level at some point upstream, meaning that some flow could conceivably bypass the gauge if some lower depression exists outside the surveyed section. Such a breakout occurs a short distance upstream of the (discontinued) gauge on the Culgoa at Woolerbilla, for instance, and there could be others of which we remain unaware at other stations.

The maximum stage for which discharge was measured was also determined from the station data supplied by DNR. This gives the limit of stage for which the discharge rating is based on measured discharge. Beyond this limit the rating curve must be extrapolated and the accuracy of the conversion from observed stage to measured discharge declines.

These values of stage are presented for the five downstream stations in **Table 2.2.**

Table 2.2: Estimated Overbank Levels and Extrapolation Limits

Station No.	Stream	Estimated Stage at which Overbank Flow Commences (m)	Maximum Stage with Measured Discharge (m)
422 206A	Narran	3.91	4.875
422 207A	Ballandool	3.868	3.666
422 208A	Culgoa	4.372	5.670
422 209A	Bokhara	2.561	2.257
422 211A	Briarie Ck	4.246	4.615

The records were then examined to determine the percentage of time flows exceeded both these limits at each station. During intervals when stage exceeded one or both these limits, the percentage of total flow represented by flow extrapolated beyond the limit was then determined.

For example, the discharge corresponding to the bank height was first determined. Let us name this the bank-full discharge. During intervals of flow exceeding bank full, the flow exceeding bank full was determined by deducting the bank-full flow. These "overbank flows" were summed and expressed as a percentage of the total flow passing that station.

These results are presented in **Table 2.3**. These results confirmed that the potential exists for significant error if the discharges are inaccurate in the extrapolated range.

Table 2.3: Potential Importance of Extrapolated and Overbank Flows

Station Number	Stream	Percent of Total Flow Exceeding Maximum Gauged Stage (%)	Percent of Total Flow Exceeding Assumed Overbank Flow Height (%)
422 206A	Narran	0.1	58
422 207A	Ballandool	40	24
422 208A	Culgoa	20	49
422 209A	Bokhara	32	20
422 211A	Briarie Ck	25	39

2.3 Extrapolation of Discharge Ratings

Given that the potential exists for significant error, the discharge ratings were examined. The precise means by which discharge ratings were extrapolated by DNR has not been determined, but it seems likely that this was achieved either through extrapolations of the cross-section areas and mean velocities of flow or by graphical means. Neither of these methods would properly account for the magnitude of overbank flow. The first method has the potential to do so, except that only small widths of the total cross-section available to flood flow have been surveyed.

Although good topographic data was not available to extend the cross-sections, the approximate width of flow at each of the stations was estimated from the flood extents in historical floods interpreted from satellite imagery (DPI, 1995 and UC, 1999). Extended cross-sections were estimated by relating the width of the flood extent to the peak stage observed at each station in each of the floods. For each flood peak this gave a point on the cross-section which could be added to extend the surveyed cross-section. These points were connected linearly.

This enabled extended cross-sections to be approximated. In future floods, new generations of satellite technology will permit greater accuracy in the determination of flood extents. A greater range of flood events will also assist in better defining the cross-section at flood stage.

For the one site on the Ballandool River at the Hebel – Bollon Road (422 207A) the satellite imagery did not reveal substantial width of overbank flow. Accordingly, the cross-section at this site was not extended and no adjustments have been made to the discharge ratings for this site.

Significant errors could be introduced into the estimated cross-sections of overbank flow at sites where it is difficult to establish the appropriate bank-full stage from the surveyed cross-sections. Even though the sites had been inspected in the field, this determination was particularly difficult for Briarie Creek, and is complicated at the Woolerbilla site on the Culgoa River because of a bypass flood runner.

The velocity of overbank flow had to be estimated, mainly from professional experience, but also supported by unofficial observations of flow velocities in the floodplain and hydraulic computations. Observations of flood flows in Cubbie Station estimated the general velocity of flow to be 0.2 m/s. Also contained within the section were preferred flow paths of limited width where velocities were appreciably higher, apparently related to patterns of vegetation growth. These observations were made during floods of moderate magnitude at different locations where overland flow was confined between levees approximately 800 m to 1 450 m apart. The artificial confinement of flows would raise mean velocities of flow.

Due to these uncertainties different values of overbank flow velocity were assumed, consistent with experience, anecdotal evidence and simple hydraulic formulae. A range of velocities from 0.075 m/s to 0.15 m/s was assumed. Based on these assumptions extrapolations of the rating between stage and discharge were calculated.

For inbank flow (*i.e.* flow within the banks), an extrapolation of measured mean velocity was used. This extrapolated velocity was used for that part of the cross-section obtained by extending vertically upwards from the point at bank-full height on either bank. Overbank area was defined by the part of the cross-section outside these verticals.

Discharge at each of the defined points on the extended cross-section (*i.e* defined from satellite imagery of historical floods) was calculated as the sum of the inbank flow plus the estimated overbank flow. A polynomial curve was fitted through the defined points in the discharge extrapolation. No change was made to discharge ratings below the range of extrapolation.

The official discharge ratings are presented in **Appendix A - Discharge Ratings and Extrapolations**. Also presented are the alternative extrapolations of the discharge ratings based on assumed overbank velocities of 0.075 m/s and 0.15 m/s. The ratings presented are the most recent ratings for each of the stations.

2.4 Estimation of Discharge

Stage records were converted to discharge using the alternative discharge ratings. As a high percentage of

flow exists in the range of extrapolated flows (refer **Table 2.3**), the effects on flow volumes are significant.

Table 2.4, **Table 2.5**, **Table 2.6** and **Table 2.7** compare the annual flow volumes as determined from the official discharge ratings, and as estimated from the alternative discharge rating in which mean velocity of overbank flow is assumed as 0.075 m/s. Substantial differences sometimes arise. The period of record shown represents the entire period of record available for each station.

Table 2.4: Comparison of Estimated Volumes of Flow in Culgoa River at Woolerbilla

Year	Volume (ML) determined from DNR ratings	Volume (ML) determined from alternative rating	Percentage Difference (%)
1966	150 355	150 355	0
1967	234 064	234 064	0
1968	182 520	182 520	0
1969	226 402	226 402	0
1970	293 081	300 443	3
1971	1 026 261	1 583 632	54
1972	553 443	607 117	10
1973	276 555	276 555	0
1974	638 571	837 079	31
1975	266 111	266 111	0
1976	1 022 815	1 256 294	23
1977	292 631	314 228	7
1978	308 781	308 781	0
1979	52 344	52 344	0
1980	9 905	9 905	0
1981	415 100	412 507	-1
1982	403 431	409 625	2
1983	1 454 132	2 378 976	64
1984	581 429	691 676	19
1985	38 352	38 352	0
1986	7 093	7 093	0
1987	23 239	23 239	0
Total	8 456 615	10 567 299	25

Table 2.5: Comparison of Estimated Volumes of Flow in Briarie Creek at Woolerbilla – Hebel Road

Year	Volume (ML) determined from DNR ratings	Volume (ML) determined from alternative rating	Percentage Difference (%)
1968	3 707	3 707	0
1969	7 118	7 118	0
1970	69 148	88 246	28
1971	325 557	410 319	26
1972	69 847	79 787	14
1973	442	442	0
1974	218 312	292 309	34
1975	186	186	0
1976	148	148	0
1977	64 127	78 843	23
1978	8 819	8 819	0
1979	0	0	0
1980	63	63	0
1981	39 932	40 907	2
1982	44 420	45 190	2
1983	781 189	1 235 524	58
1984	257 328	366 792	43
1985	82	82	0
1986	6	6	0
1987	0	0	0
1988	263 155	363 350	38
1989	38 709	38 709	0
1990	158 611	215 115	36
1991	673	673	0
1992	0	0	0
1993	3 049	3 049	0
1994	62 319	68 205	9
1995	6 595	6 595	0
1996	321 400	467 308	45
1997	69 420	69 420	0
1998	141 964	184 216	30
Total	2 956 326	4 075 127	38

Table 2.6: Comparison of Estimated Volumes of Flow in Bokhara River at Hebel

Year	Volume (ML) determined from DNR ratings	Volume (ML) determined from alternative rating	Percentage Difference (%)
1966	8 654	8 654	0
1967	15 855	15 855	0
1968	13 460	13 460	0
1969	16 967	16 967	0
1970	30 317	28 743	-5
1971	180 201	168 310	-7
1972	55 671	54 555	-2
1973	6 941	6 941	0
1974	125 907	118 127	-6
1975	21 251	21 251	0
1976	170 248	168 504	-1
1977	64 095	64 001	0
1978	59 510	59 510	0
1979	19 100	19 100	0
1980	4 739	4 739	0
1981	74 761	74 761	0
1982	67 135	67 135	0
1983	436 107	363 860	-17
1984	231 472	202 732	-12
1985	19 145	19 145	0
1986	588	588	0
1987	10 648	10 648	0
1988	175 064	159 925	-9
1989	73 973	73 973	0
1990	110 931	98 509	-11
1991	4 870	4 870	0
1992	11 550	11 550	0
1993	4 173	4 173	0
1994	36 998	36 998	0
1995	15 411	15 411	0
1996	155 318	137 634	-11
1997	47 997	47 997	0
1998	72 068	70 802	-2
Total	2 341 125	2 169 427	-7

Table 2.7: Comparison of Estimated Volumes of Flow in Narran River at Dirranbandi – Hebel Road

Year	Volume (ML) determined from DNR ratings	Volume (ML) determined from alternative rating	Percentage Difference (%)
1966	44 989	48 691	8
1967	76 546	78 604	3
1968	53 382	53 382	0
1969	82 414	88 504	7
1970	168 342	178 340	6
1971	691 942	673 537	-3
1972	293 879	313 526	7
1973	62 425	62 425	0
1974	321 239	344 692	7
1975	123 051	122 442	0
1976	665 262	675 872	2
1977	150 142	166 385	11
1978	118 935	126 430	6
1979	20 387	20 387	0
1980	4 869	4 869	0
1981	198 985	230 292	16
1982	171 542	200 693	17
1983	1 236 695	1 060 696	-14
1984	552 981	507 615	-8
1985	19 367	19 367	0
1986	165	165	0
1987	10 833	10 833	0
1988	493 953	510 613	3
1989	255 648	288 638	13
1990	247 803	205 132	-17
1991	21 840	21 840	0
1992	12 802	12 802	0
1993	32 363	36 411	13
1994	126 176	151 051	20
1995	90 408	91 373	1
1996	539 135	481 053	-11
1997	154 931	177 398	15
1998	258 608	285 001	10
Total	7 302 039	7 249 059	-1

It must be stated that these results do not accurately portray the error in the flow volumes introduced by the discharge ratings. Due to the limitations of the data used to estimate them, errors in the extensions of the cross-sections and in the assumed velocity of overland flow will be inherent in the alternative discharge ratings too.

The results do however present that very different outcomes are possible based on a credible alternative approach to extrapolation of discharge ratings. It illustrates that the accuracy of the results being used to support technical studies and management strategies is low, and that the volumes of flow in the lower floodplain are potentially under-estimated by a significant margin. More work is justified to reduce the margin of error which has been identified.

2.5 Implications for the Water Balance

The water balance in the Lower Balonne floodplain is examined by comparing the combined flows at three levels:

(1) just downstream of St George, where station 422201 gauges the flow;

(2) near the first flow split, where stations 422204 and 422205 on the Culgoa at Whyenbah and Balonne Minor at Hastings contain most of the flow, although overland flows can develop at higher stages (at flows exceeding 100 000 ML/d a major breakout to the east occurs);

(3) near the NSW border, where stations 422206, 422207, 422208, 422209 and 422211 gauge the channel flow in the Narran, Bokhara, Ballandool and Culgoa Rivers, and Briarie Creek, but as we have seen may under-estimate overland flow.

Table 2.8 compares the combined volume of flow (ML) at these three levels in the floodplain assuming an overbank flow velocity of 0.075 m/s. For levels one and two (downstream of St George and at Whyenbah) the DNR official ratings are the only source of data whereas at level three near the NSW border a comparison is made between the official DNR ratings and the flows calculated from the adjusted ratings. The period of record selected for this comparison represents the period during which all five border stations were in operation (1968 – 1987).

Table 2.8: Water Balance in the Lower Balonne (v=0.075m/s case)

Year	Volumes at St. George (1)	Volumes Near First Flow Split (2)	Volumes Near NSW Border (3)		
			DNR	Adjusted	Potential Error (%)
1968	327 828	287 704	259 936	259 936	0
1969	478 742	411 109	344 607	350 697	2
1970	1 513 758	1228 877	595 238	630 122	6
1971	3 209 556	2812 479	2 452162	3063 999	25
1972	1 453 180	1442 697	1 029 183	1111 328	8
1973	381 730	374 487	348 712	348 712	0
1974	1 504 732	1763 252	1 423 266	1711 444	20
1975	608 789	666 218	428 982	428 373	0
1976	2 193 075	2415 311	2 017 704	2260 050	12
1977	1 003 246	976 063	619 029	671 490	8
1978	594 672	619 692	517 701	525 196	1
1979	130 519	145 242	98 055	98 055	0
1980	43 609	37 810	21 595	21 595	0
1981	1 171 126	1158 559	779 856	809 545	4
1982	846 117	939 467	731 837	767 952	5
1983	7 379 795	6116 269	4 492 662	5623 595	25
1984	2 571 642	2794 303	1 796 256	1941 860	8
1985	106 911	100 036	84 555	84 555	0
1986	23 943	15 212	7 980	7 980	0
1987	94 796	95 229	49 416	49 416	0
1968-1987	25 637 766	24 400 016	18 098 732	20 765 901	15
Losses from St George to near Hebel			29 %	19 %	

Results show that, in general, there is a modest reduction in flow between St George and Whyenbah near the first flow split. Flows estimated from the official discharge ratings for the five stations near the NSW border indicate a substantial reduction in flow from Whyenbah down to the transect near Hebel – Woolerbilla.

Flows estimated from the alternative rating (v=0.075m/s) show a lesser reduction in flows from Whyenbah down to the transect near Hebel – Woolerbilla suggesting that the reduction in flows downstream of Whyenbah may be over-estimated to the order of 15 %.

This alternative data set also gives a total loss of flow between St George and Hebel of 19 % as compared with 29 % as stated by DNR. It could well be less.

Two graphs have also been prepared to demonstrate the impact of the adjusted ratings at the five downstream gauges. **Graph 1** is a column chart showing the annual flow volumes at the St George gauge, at the two middle gauges (Whyenbah and Hastings) and at the five downstream gauges using the official and adjusted ratings. **Graph 2** is a line graph showing the annual flow volume at St George and the losses calculated between St George and the border gauges using the official and adjusted ratings. The period of record from 1968 to 1987 applies to both graphs.

A similar analysis has been undertaken for an assumed overbank flow velocity of 0.15 m/s. **Table 2.9** demonstrates the summarised water balance for the same period of record.

Table 2.9: Water Balance in the Lower Balonne (v=0.15m/s case)

Year	Volumes at St. George (1)	Volumes Near First Flow Split (2)	Volumes Near NSW Border (3)		
			DNR	Adjusted	Potential Error (%)
1968-1987	25 637 766	24 400 016	18 098 732	27 479 177	52

Flows estimated from the alternative rating (v=0.15m/s) show an increase in flows from Whyenbah down to the transect near Hebel – Woolerbilla. Although this is unlikely to be correct since there are no significant tributaries between St George and the border and losses may be expected to exceed local runoff from rainfall in this area, it does demonstrate that the reduction in flows downstream of Whyenbah may be quite significantly over-estimated. These inconsistent results have been presented to demonstrate that the upper limit for velocity on the overbank is likely to lie between 0.075 m/s and 0.15 m/s.

A similar exercise has been undertaken for three actual flood events to demonstrate the potential errors in the water balance in the Lower Balonne floodplain. Three

events have been selected during the 1980s when the Culgoa River gauge remained operational.

- May 1988
- December 1983
- March 1982

Table 2.10 demonstrates the water balance for these events assuming an overbank velocity of 0.075 m/s. For the largest flood event selected (May 1988), the potential error in losses between St George and near Hebel is reduced from DNR's estimation of 39 %, to 27 % using the adjusted ratings. This effect is not as pronounced for the smallest of the three events (March 1982).

Table 2.10: Water Balance in the Lower Balonne for Actual Events

Event	Volumes at St. George (1)	Volumes Near First Flow Split (2)	Volumes Near NSW Border (3)		
			DNR	Adjusted	Potential Error
May 1988	2 075 185	1 788 044	1 272 215	1 520 475	20 %
Losses from St George to near Hebel			39 %	27 %	
Dec 1983	1 047 004	1 005 112	655 089	769 611	17 %
Losses from St George to near Hebel			37 %	26 %	
March 1982	630 597	674 402	510 093	544 270	7 %
Losses from St George to near Hebel			19 %	14 %	

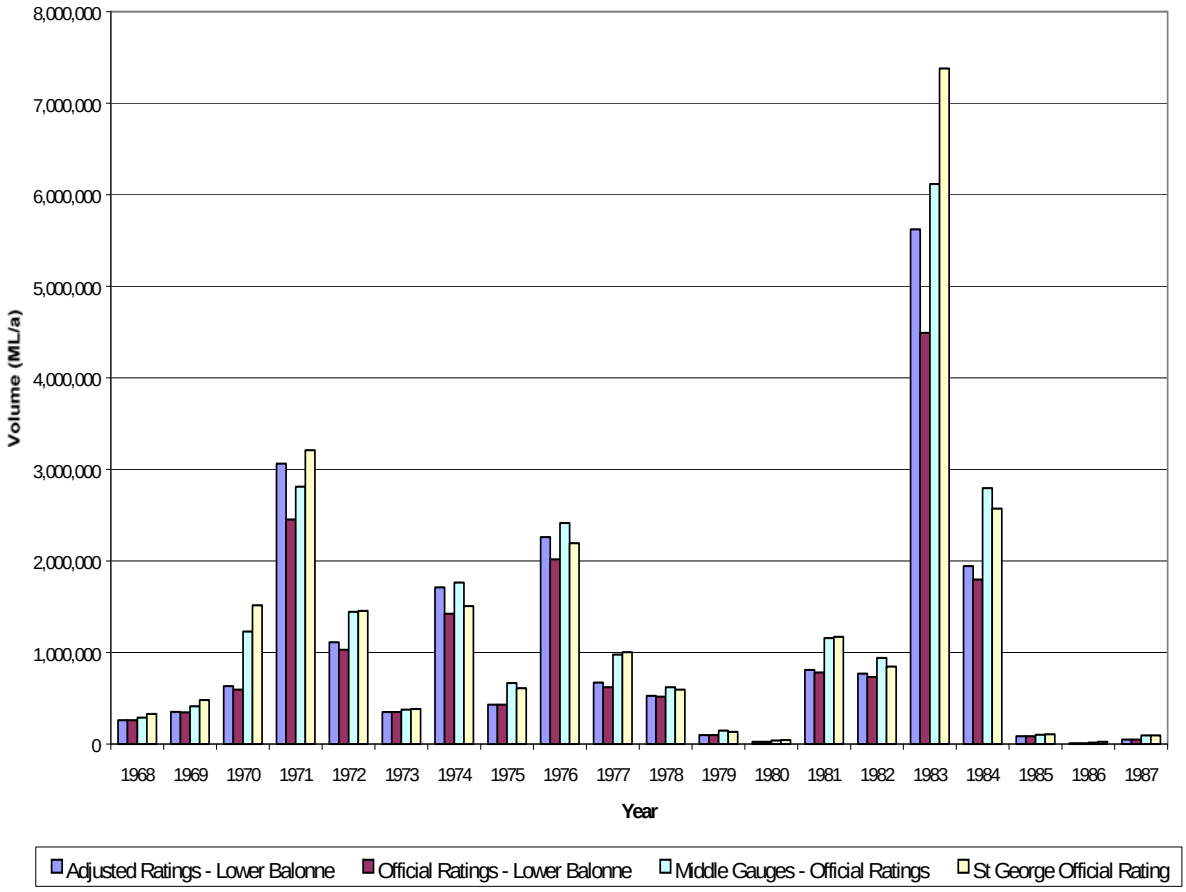
2.6 Conclusions

As noted previously, the volumes of flow in the lower floodplain are potentially under-estimated by a significant margin, which means that the accuracy of the results being used to support technical studies and management strategies is potentially low.

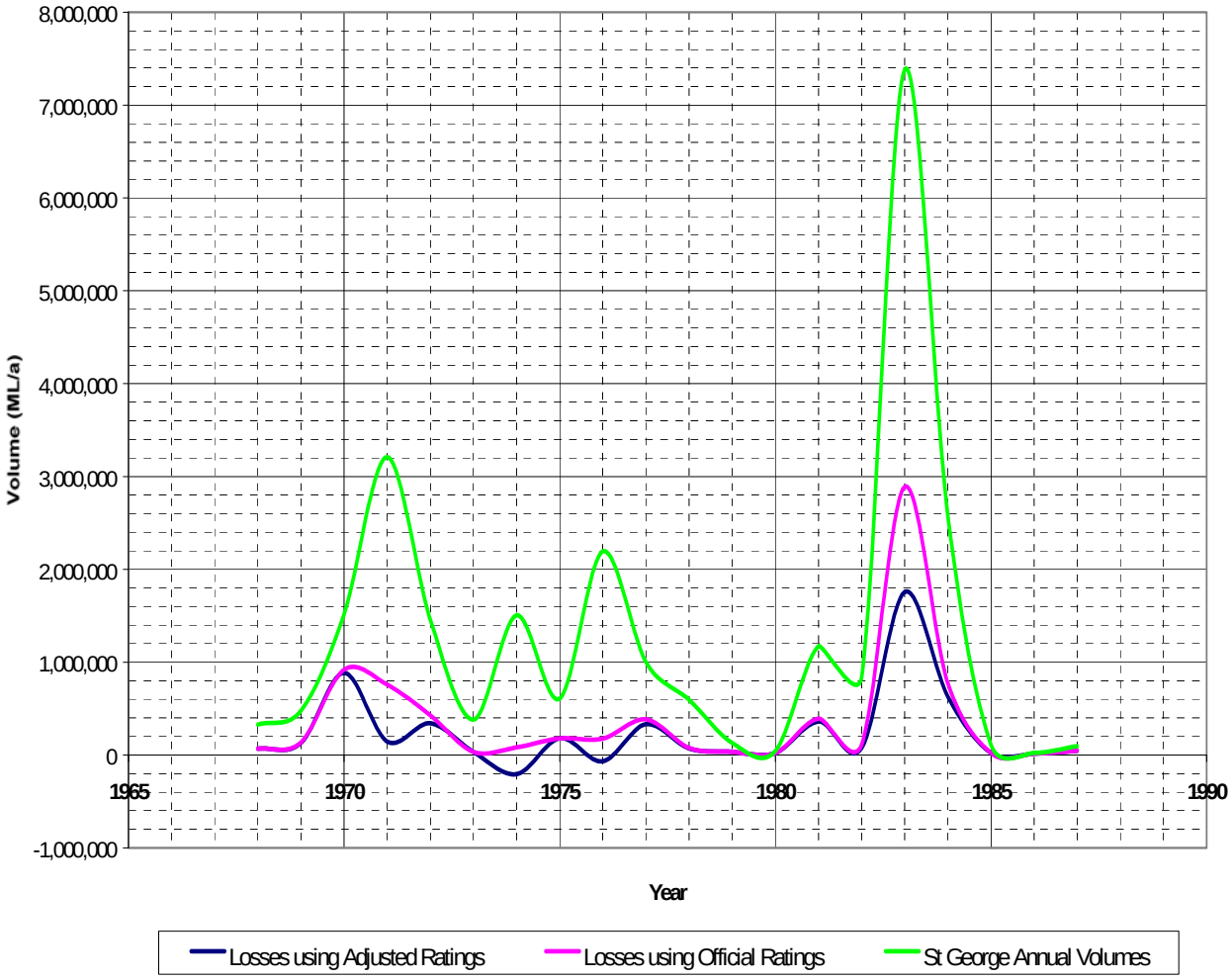
This conclusion has been recognised previously in a report undertaken for the Border Rivers Commission (DPI, 1993) in which it was noted that “further gauging at high flow levels are required on the Culgoa River in Queensland and on all streams in NSW so that the models will more adequately simulate the patterns of water distribution”.

This study was not intended to provide a definitive quantification of the error inherent in the flow records. It has demonstrated that the potential error is quite large and that additional work is required to quantify flows more accurately, particularly if they are to be used as the basis for elaborate technical studies and important management strategies.

Graph 1: Annual Flow Volumes at St George Gauge, Middle Gauges and Lower Balonne Gauges

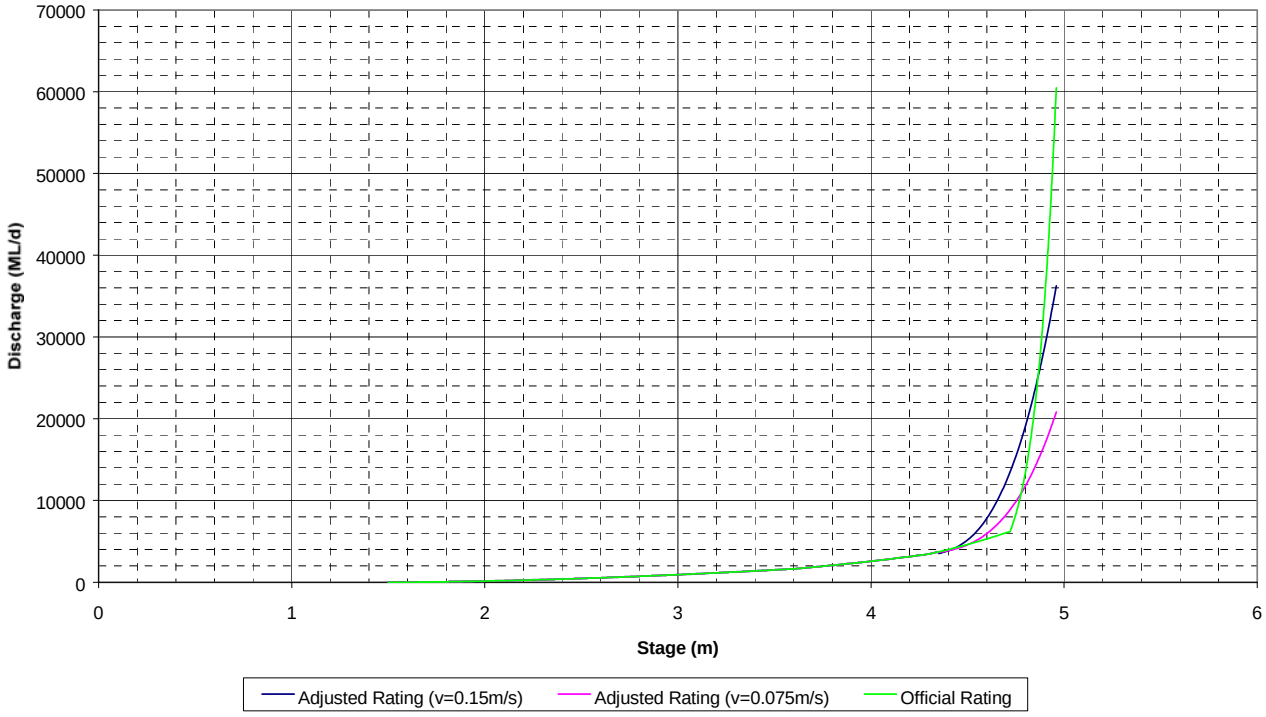


Graph 2: St George Annual Volume & Losses between St George and Lower Balonne Gauges

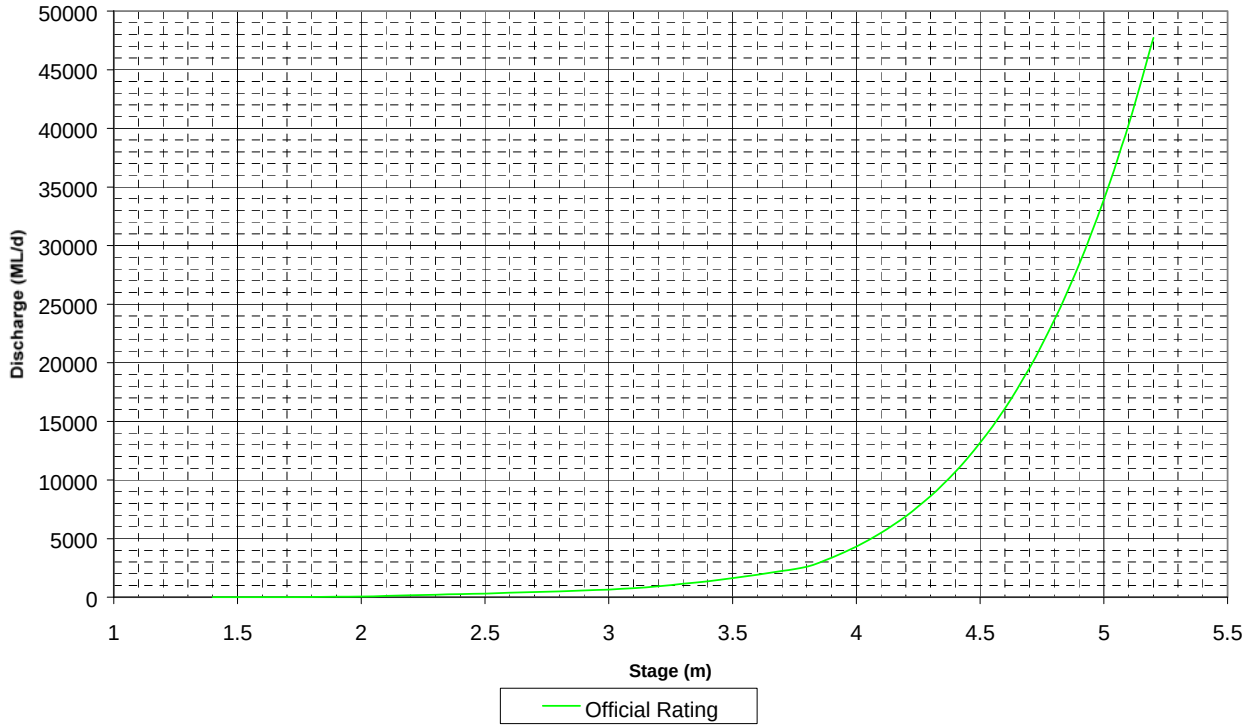


Appendix A - Discharge Ratings and Extrapolations

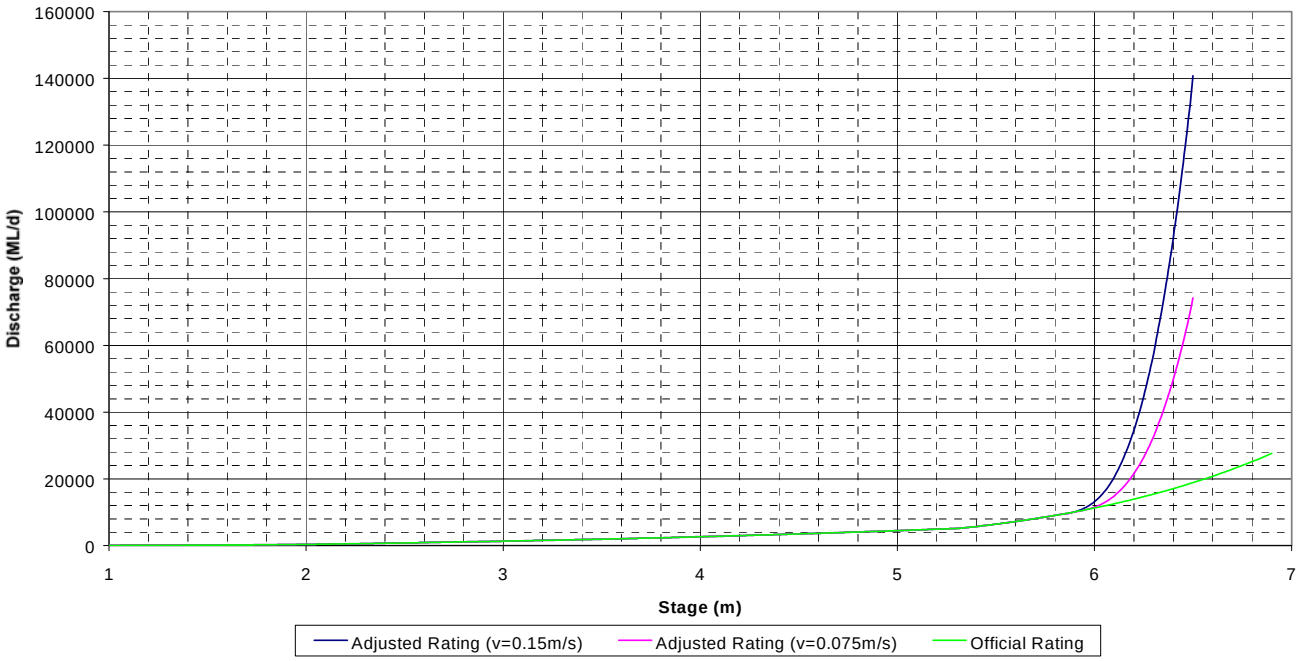
Rating Curve at Narran River (422 206A)



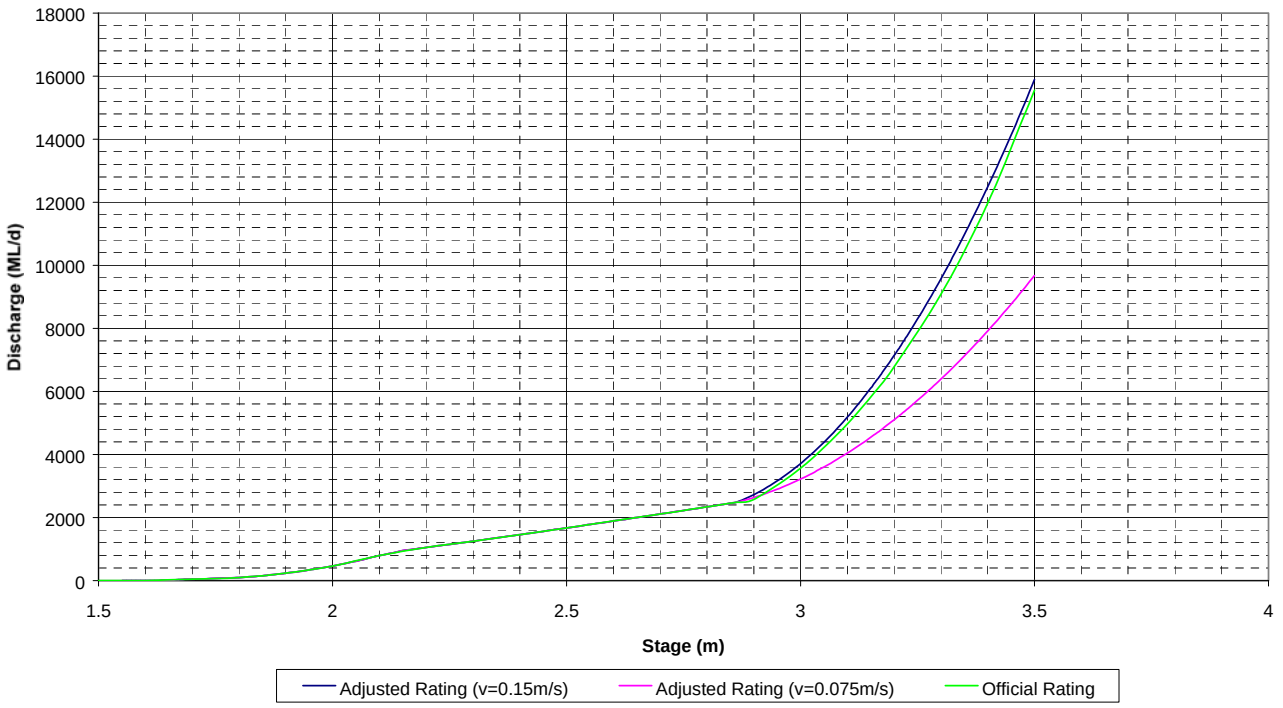
Rating Curve at Balandool (422207A)

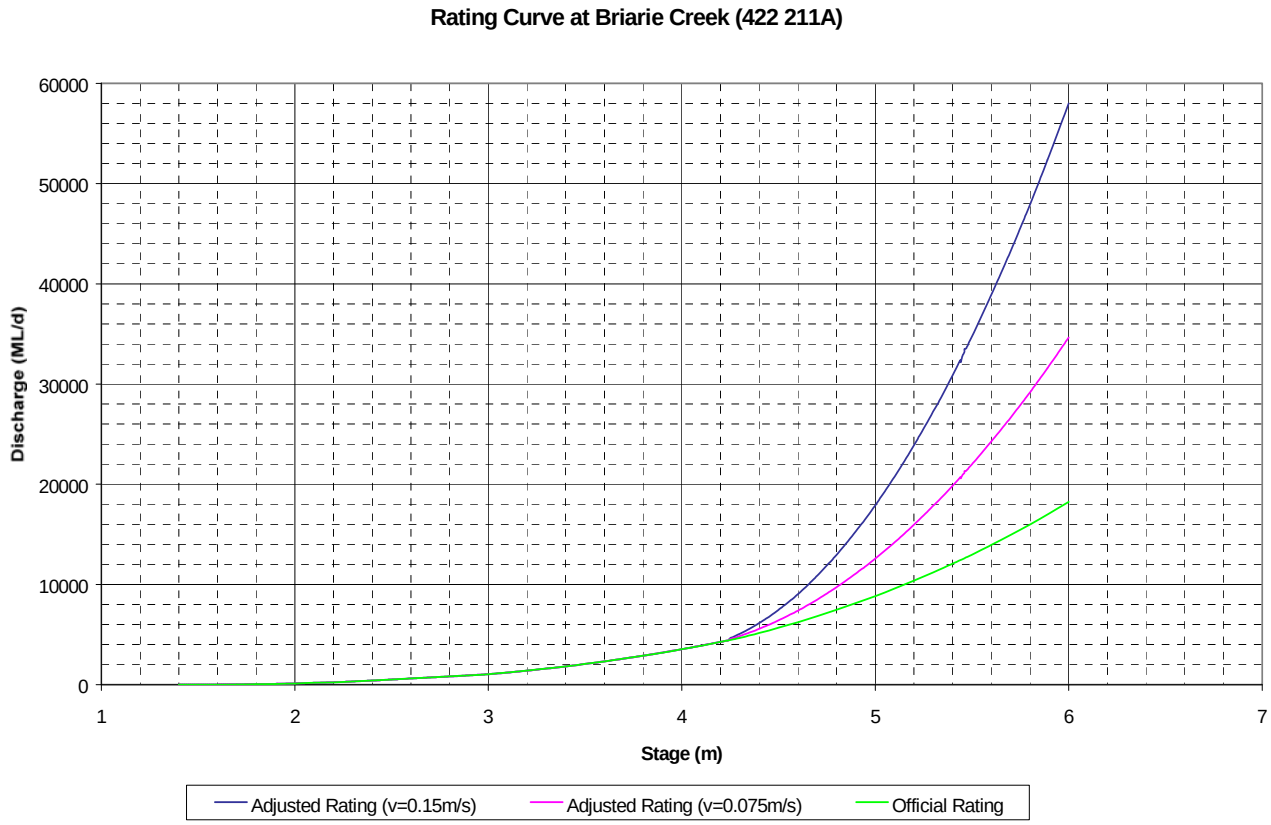


Rating Curve at Culgoa River (422 208A)



Rating Curve at Bokhara River (422 209A)




Rating Curve at Briarie Creek (422 211A)
Discharge (ML/d)
60000
50000
40000
30000
20000
10000
0
1
2
3
4
5
6
7
Stage (m)
Adjusted Rating (v=0.15m/s)
Adjusted Rating (v=0.075m/s)
Official Rating

Appendix B - Estimated Flows at Cubbie Station

Location	Event	Water Level (m)	Depth (m)	Discharge		Velocity	n=0.100
				(m3/s)	(ML/d)	(m/s)	
Chinaman Floodway	Sep-98	163.849	1.149	357	30845	0.21	
	Mar-99	163.455	0.755	177	15293	0.16	
Doctors Creek	Sep-98	163.573	0.873	121	10454	0.17	
	Mar-99	163.618	0.918	132	11405	0.18	

Location	Event	Water Level (m)	Depth (m)	Discharge		Velocity	n=0.080
				(m3/s)	(ML/d)	(m/s)	
Chinaman Floodway	Sep-98	163.849	1.149	446	38534	0.27	
	Mar-99	163.455	0.755	221	19094	0.2	
Doctors Creek	Sep-98	163.573	0.873	152	13133	0.22	
	Mar-99	163.618	0.918	165	14256	0.22	

Estimations above based on use of Manning's equation.

Observations of flows in the floodways are that in general flow velocities are approximately 0.2 m/s, with preferred flowpaths of limited lateral extent in which velocities may be up to 1.0 m/s. If we assume that the preferred flowpaths make up 5% of the floodway cross-section, this provides a rough estimate of mean velocity over the whole cross-section of 0.24 m/s. This is tolerably consistent with the results above, however it is likely the observations may have over-estimated flow velocities.