MURWEH SHIRE COUNCIL

95-101 Alfred Street, Charleville
A.B.N. 98 117 909 303

9th March 2011

YOUR REF: Richard Ranson
IN REPLY CONTACT:
RESPONDS TO:
OUR REF:

RECEIVED
11 MAR 2011
IN DRM

Hub of the South West

The Honourable Justice Catherine Jones
Commissioner,
Queensland Floods Commission of Inquiry
GPO Box 1738,
BRISBANE QLD ~~4470~~ 4001

ADDRESS ALL COMMUNICATIONS TO:
THE CHIEF EXECUTIVE OFFICER

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Dear Justice Holmes,

RE: Request for Information by Commissioner of Inquiry

Please find enclosed documents in response to your request for information pertinent to the Queensland Floods Commission of inquiry. The following are included.

1. Copy of flood management study

2. Flood mitigation update report (March 2011) and flood mitigation activities timeline

3. A letter from the Mayor of Murweh Shire Regarding LDMG & DDMG review

4. Documents pertaining to vegetation conditions and management

11,12,13. Bureau of Meteorology report into floods containing stream gauging information, river height & velocity, and data into extent of flooding

15. Documents relating to flooding and flood mitigation measures

19. Copy of local disaster management plan (March 2010), including evacuation plans and list of members of local disaster management group

22. Local disaster management meeting minutes

23. Situation reports prepared by local disaster management group

[redacted]

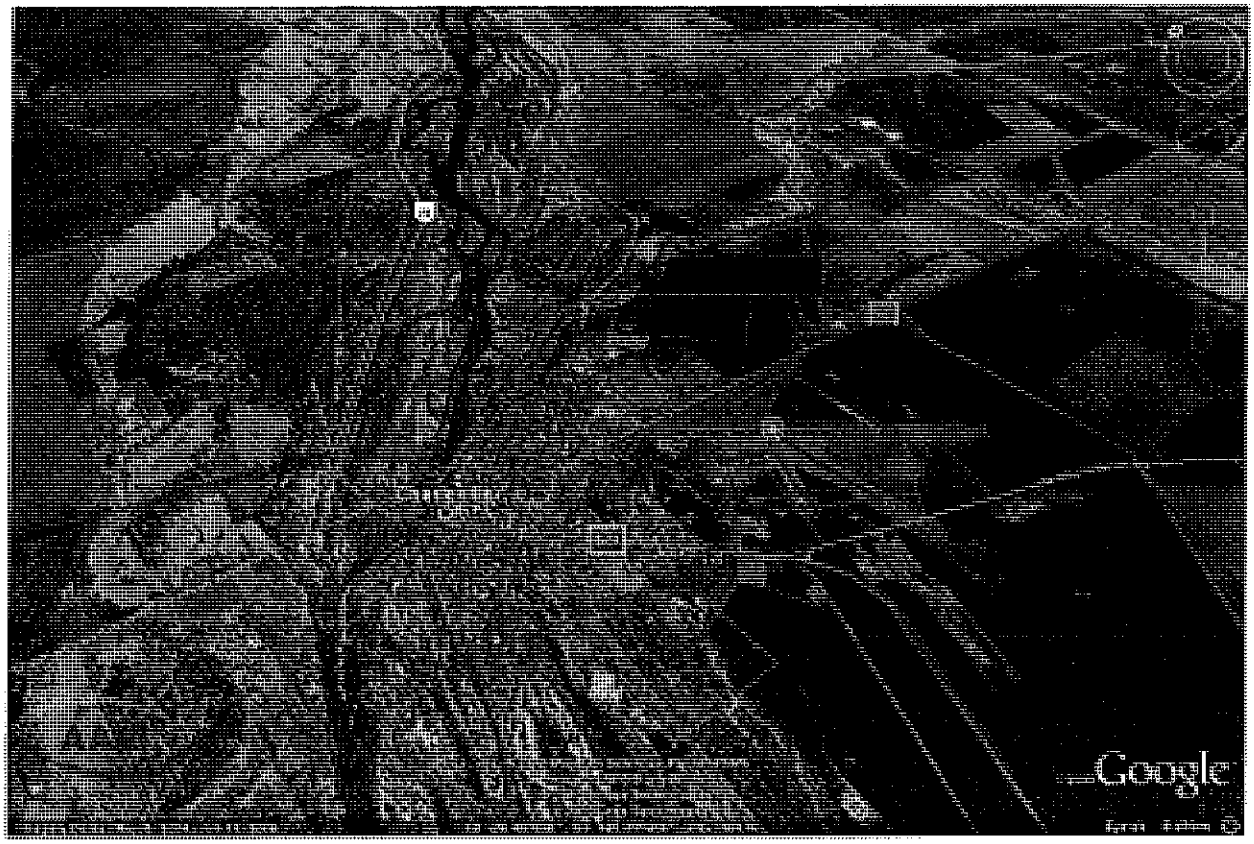
C.D. BLANCH
CHIEF EXECUTIVE OFFICER

QFCI

Date: 11/11/11 JM

Exhibit Number: 1019

Murweh Shire Council



Bradley's Gully - Charleville
Initial Flood Management Study
Final Report

July 2010

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Bradley's Gully - Charleville
Initial Flood Management Study
Final Report

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Executive Summary

Introduction
Murweh Shire Council (MSC) appointed Sargent Consulting (SC) in May 2010 to undertake an Initial Flood Mitigation Study in respect of flooding of Charleville specifically from Bradley's Gully, in the light of major flooding which occurred in March 2010.

The aim of the Initial Study is *"to précis and provide expert advice and recommendations to the Murweh Mitigation Group and Council regarding possible acceptable solutions for flood mitigation of Bradley's Gully.* ***These recommendations are to provide the basis for a further funding submission for an in-depth study of the acceptable solutions."*** (quote from Initial Brief).

The Initial Study was undertaken over a nine week period in order to be able to provide early advice in respect of further funding requirements for the in-depth study and subsequent construction works. Brief weekly progress reports were provided throughout this period.

An *Interim Report* was submitted in June 2010 to provide feedback to Council and the Murweh Flood Mitigation Group in respect of the progress of the study to its mid point.

This Report is the *Final Report* for the Initial Study. It presents new material from work undertaken subsequent to the presentation of the *Interim Report* including recommendations for the proposed detail Study, and also includes information from the *Interim Report* in order to provide a single consolidated report. The recommendations contained in this Report supersede those made in the *Interim Report.*

It should be noted that this commission has regard principally to structural flood mitigation measures, and that others are responsible for non-structural approaches to reducing future flood impacts.

Summary of 2010 Flood
The March 2010 flood was caused by a severe low pressure system originating within the monsoon trough over the Northern Territory on 22nd February 2010, moving over Queensland and causing widespread rainfall over a wide area, including the Warrego River catchment, in the first week of March.

The Bradley's Gully flood was the result of rainfall of 250mm over the period 1st to 4th March 2010, 100mm of which fell in 8 hours from 5pm on 1st March. The maximum 1 hour rainfall was 20mm. Rainfall was widely distributed over the catchment with very similar totals being recorded at Charleville and at Raceview. This rain fell on an already wet catchment resulting in a relatively large proportion of runoff. Rainfalls in the Upper Warrego catchment were much less than around Charleville.

Analysis of the rainfall and of the estimated peak flow both indicate that this flood was about 50 year Average Recurrence Interval (ARI) or 2% Annual Exceedance Probability (AEP).

The exclusion of the Bradley's Gully Diversion and the upstream return section of the levee from the Stage 1 scheme did not allow for the natural breakout which occurs from Bradleys Gully in the vicinity of Burcher Street back into the Warrego river near Hunter Street. The small diameter pipes constructed through the levee in the vicinity of Hunter Street are totally inadequate in catering for return of this overflow to the river, and were, presumably, designed to cater for local storm runoff

only. This resulted in the breakout flow being trapped behind the levee and turning south west to flow inside the levee. Some of this flow exited from behind the levee at the gap at the Mitchell Highway crossing and some flowed back into Bradley's Gully exacerbating flood levels.

Community Consultation
The consultation period ran from 11th – 21st May 2010 and was advertised prior to the arrival of the consultants through local radio and print media and the circulation of flyers through the business district. In all, a total of 41 submissions were recorded. This included a submission from the Chamber of Commerce which itself includes a number of individual submissions resulting from a public meeting called by the Chamber on 23rd March 2010.

As Council is aware, there is a great deal of community feeling that the flooding issues in Charleville need to be resolved urgently, and that if there is another flood which causes widespread damage it will have serious consequences for the town's future; as many businesses could not sustain further loss. Also some residents have already relocated elsewhere and more would be likely to do so if flooded again.

Whilst primarily focussed on community suggestions for flood mitigation in respect of Bradley's Gully, a number of other issues were raised. In addition to the widespread concern regarding the recent floods, the issues and the suggested actions can be categorised as follows:

- Bradley's Gully - Diversion;
- Bradley's Gully – other flood mitigation;
- Charleville Levee;
- Warrego River; and
- Flood warning, dissemination of warnings and evacuation.

Table ES1 summarises the submissions received according to the above classification, and gives the number of individual submissions containing that suggestion. **Table ES1** shows these numbers in descending order of popularity in each of the classifications.

Hydrologic and Hydraulic Modelling
Hydrologic modelling of the Bradley's Gully catchment was undertaken which estimated that the March 2010 flood had a peak flow of about 1,000m^3/s and an annual exceedance probability (AEP) of about 2% or 1 in 50 (or an average recurrence interval (ARI) of about 50 years).

Preliminary hydraulic modelling of Bradley's Gully through Charleville was undertaken initially to refine the estimates of flow capacity of the Gully through the town, and was also used to evaluate the effectiveness of a range of flood mitigation options in reducing the extent of flooding in the town. The body of the report includes maps of flood extent for the recent flood and for various flood mitigation options.

Table ES1 Summary of Community Submissions

Suggestions/ Proposed Actions	Number
Bradley's Gully - Diversion	
Diversion of Bradley's Gully to Warrego River upstream of the town (12 no location, 7 at Raceview, 2 further upstream)	21
Diversion of Bradleys Gully south to Angellala Ck/Fifteen Mile Ck	5
Diversion of Bradleys Gully across railway tracks near Morven Road	3
Diversion of Bradleys Gully across railway tracks near hospital	1
Multi-channel system with diversions/flood gates	1
Bradley's Gully - Other	
Deepen the Gully through town and/or downstream, clean out culverts and/or increase culvert sizes	11
Upstream flood mitigation storage	5
Raise houses flooded in 2008	2
Develop linear park	1
Plant trees in Gully - scouring will maintain depth.	1
Realign Gully crossing at Parry St	1
Provide industrial land for business relocation to higher ground	1
Levee	
Replace small drains through levee near Hunter St with floodgates or permanent pumps	8
Increase levee height to 1990 protection	3
Concerns with levee construction	3
Warrego River	
Clearing out the river channel (non specific)	6
removal of "The Island"	3
Increase waterway area in Mitchell Highway crossing	3
"Big River" submission	2
Reinstate former flood channel on right bank of Warrego R near Pretty Pines (cut off by Augathella Road)	1
Build check dams in Warrego/Neve Rivers	1
Flood Warning, Dissemination and Evacuation	
Flood Mitigation Plan, Flood Action Plan etc	2
Improve flood warning system (including signs, sirens) SMS	2
Improve flood operation preparedness	1
Increase SES volunteer numbers	1
Increase SES volunteer numbers	1
Improve public information	1
General	
Move the town	1

Option Evaluation
Flood mitigation options both from community submissions and from our own technical considerations have been categorised as follows:

- Bradley's Gully - Diversion;
- Bradley's Gully – other flood mitigation;
- Charleville Levee;
- Warrego River;
- Flood warning, dissemination of warnings and evacuation; and
- General.

Of these categories, only the first four fall within the Scope of Work of the current study, and brief comments on these are given in the following paragraphs.

The evaluation was undertaken on the primary criterion of providing protection against a flood of 1% annual exceedance probability (AEP) (also referred to as 100 year Average Recurrence Interval (ARI)) which is the usual design criterion adopted in Australia. The 2010 flood was about 2% AEP (50 year ARI), so this design flood caters for a flood worse than that which occurred this year.

It must be recognised however, that there is a 1% chance of this flood being exceeded each year, so a larger flood will occur at some time in the future. Whilst such a flood will result in some flooding, it will be much reduced compared to current flooding if the proposed works are constructed. It is important that the proposed works are resilient in the event that their design capacity is exceeded. This aspect has been considered only qualitatively in this Initial Study, but should be considered in more detail in the detail study.

Four potential diversion routes upstream of Charleville and two retarding basin options were evaluated in detail as being the most likely means of providing a long term solution to flooding from Bradley's Gully. Each of these were dealt with in the body of the report.

Cost Estimation
The cost estimates presented in this Report are preliminary in nature and are subject to confirmation as part of the proposed detail studies, and subsequently when the projects are tendered.

The cost estimates have been developed from the concept level designs by extracting the quantities of the main items within each option and applying appropriate unit rates.

In order to cover a reasonable degree of variation in the unit rates, a contingency of 30% has been added which is a typical value for preliminary estimates (in a typical range of 20% to 40%). A further 6% has been allowed for engineering and 6% for construction supervision.

We believe that the estimated costs are reasonable and sufficiently conservative to cover any anticipated variations due to the current uncertainty in relation to the suitability of materials for embankment construction in particular.

The costs of all of the diversion options are increased by the need to protect the channel bed and banks from erosion as a result of flood velocities approaching 3m/s, compared to the maximum which can be passed by an unlined channel without significant erosion of about 1.2m/s.

Table ES2 gives the estimated costs.

Table ES2 Cost Estimation Summary – Major Works only

Option Type	Option	Outline Description	Estimated Cost $ million
Diversion from Bradley's Gully upstream of Charleville	Diversion A	Channel excavation, levees, Alfred St culvert, Diversion weir	17
	Diversion B	Channel excavation, levees, Alfred St culvert, Diversion weir	20.
	Diversion C	Channel excavation, levees, Wellwater Rd culvert, Diversion weir	30
	Diversion D	Channel excavation, levees, Wellwater Rd culvert, Diversion weir	33
Retarding Basin on Bradley's Gully	Site 1	Retarding Basin FSL 313m AHD, Crest Level 316m AHD 1800 dia outlet 25m wide spillway Storage to FSL 26000ML Plus diversion weir on Bradley's Gully and extension of levee east of Hunter St to the Gully	22
	Site 2	Retarding Basin FSL 317m AHD, Crest Level 320m AHD 1800 dia outlet 32m wide spillway Storage to FSL 41000ML Plus diversion weir on Bradley's Gully and extension of levee east of Hunter St to the Gully	34
NOTE: All quoted costs are exclusive of GST			

Of the diversion channel options, although Option A has the lowest cost, its proximity to the urban area is a significant disadvantage, as any overtopping of the levee forming the left bank of the diversion, in a flood exceeding design conditions, will immediately cause property flooding. This option also requires resumption of a number of properties or parts of properties in the town area. Because of this, we recommend that this option be discounted from further consideration.

Of the other options, Option B offers the next lowest cost and avoids all buildings, and has no known disadvantages compared to the other options. In common with the other options, this will require some partial property resumptions. Hence, option B is the preferred diversion option.

The operation of the diversion with concurrent flood in the Warrego River was evaluated by running the models with a fixed high flow in the Warrego River of 2,400m^3/s corresponding to the peak flow in the 1997 flood (Egis 2000). This showed an increase in maximum flood level averaging 0.5m.

Of the two retarding basin options evaluated, that at Site 1 is preferable both in terms of costs and ability to restrict downstream flows. Site 1 is the closest viable site to the town, and hence has the lowest local runoff entering Bradley's Gully downstream of the structure.

However, because of this downstream inflow, neither of the retarding basin options alone can reduce the flow in the town reach of Bradley's Gully to its bank full capacity without additional works. This would comprise a small diversion weir with low flow pipe of 1,500mm diameter, an extension of the existing levee from the diversion weir to the existing levee near Hunter Street, and discharge pipes through the levee.

Concept drawings of these preferred options are given in **Figures ES1** and **ES2.**

Conclusions

We have concluded from the option evaluation undertaken for this study that the most viable flood mitigation options for Bradley's Gully are either:

- A retarding basin constructed on the Gully upstream of Charleville to significantly reduce peak flood flows through the town reach of the Gully by temporarily storing floodwaters (at the location referred to herein as Site 1); or
- Diversion of Bradley's Gully into the Warrego River upstream of the town, at the location referred to herein as Option B.

However, any of the diversion options will increase the flood level in the Warrego River should both Bradley's Gully and the Warrego River be in flood at the same time. We have modelled the scenario in which the Warrego River 1997 flood which is the design flood for the current Stage 1 levee coincides with a 1% AEP (100 year ARI) flood in Bradley's Gully with diversion option B, and this showed a 0.5m increase in river flood level. This combined flood can still be passed without overtopping the levee as this diversion was included in the design (Egis 2000).

On the other hand, the retarding basin options only discharge to the Warrego River via their spillways once their storage is full, and these are very small flows in the case of the 100 year ARI (1% AEP) flood. Similarly, in more extreme floods, up to 500 year ARI (0.2% AEP) (the maximum flood tested), the spillway flows were still very modest compared to the river flows. Also, the retarding basin will probably be a referable dam under the *Water Supply (Safety and Reliability) Act (2008)* requiring DERM licensing, performance monitoring and a high level of maintenance.

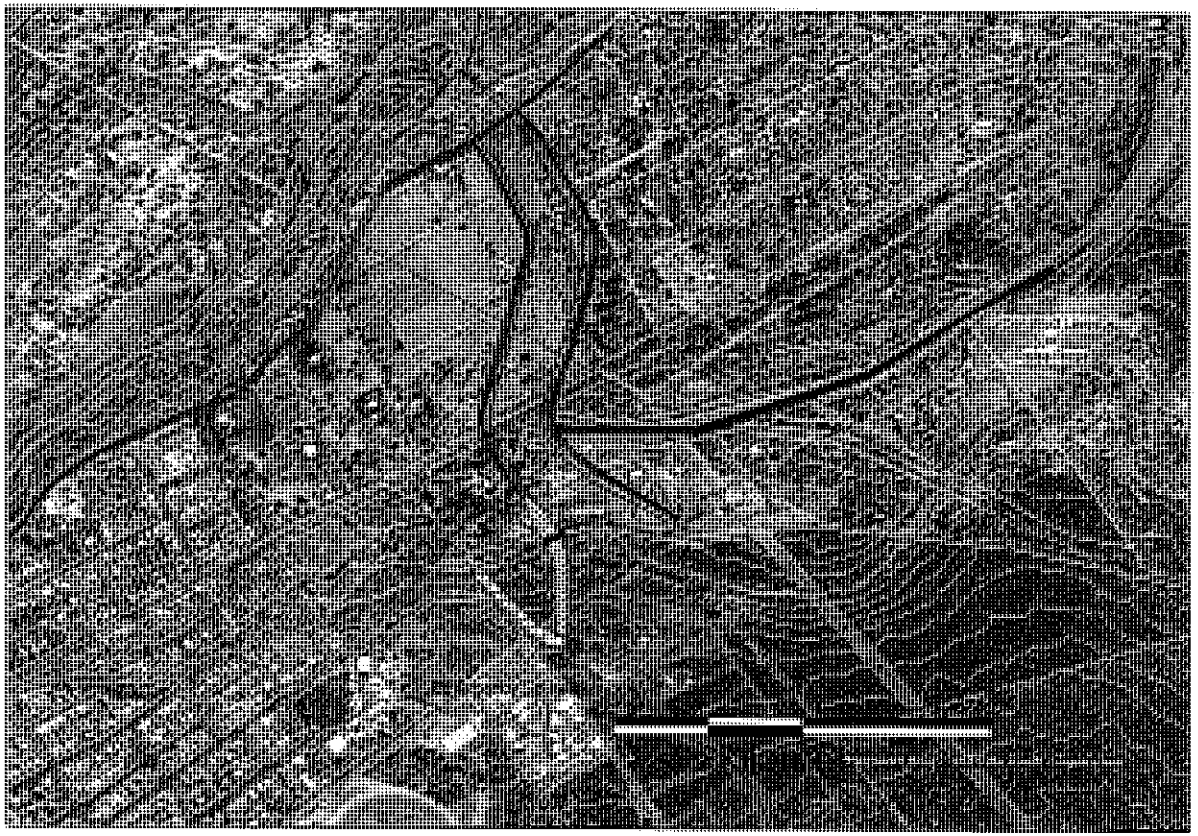

Figure ES1 Concept Plan - Diversion B

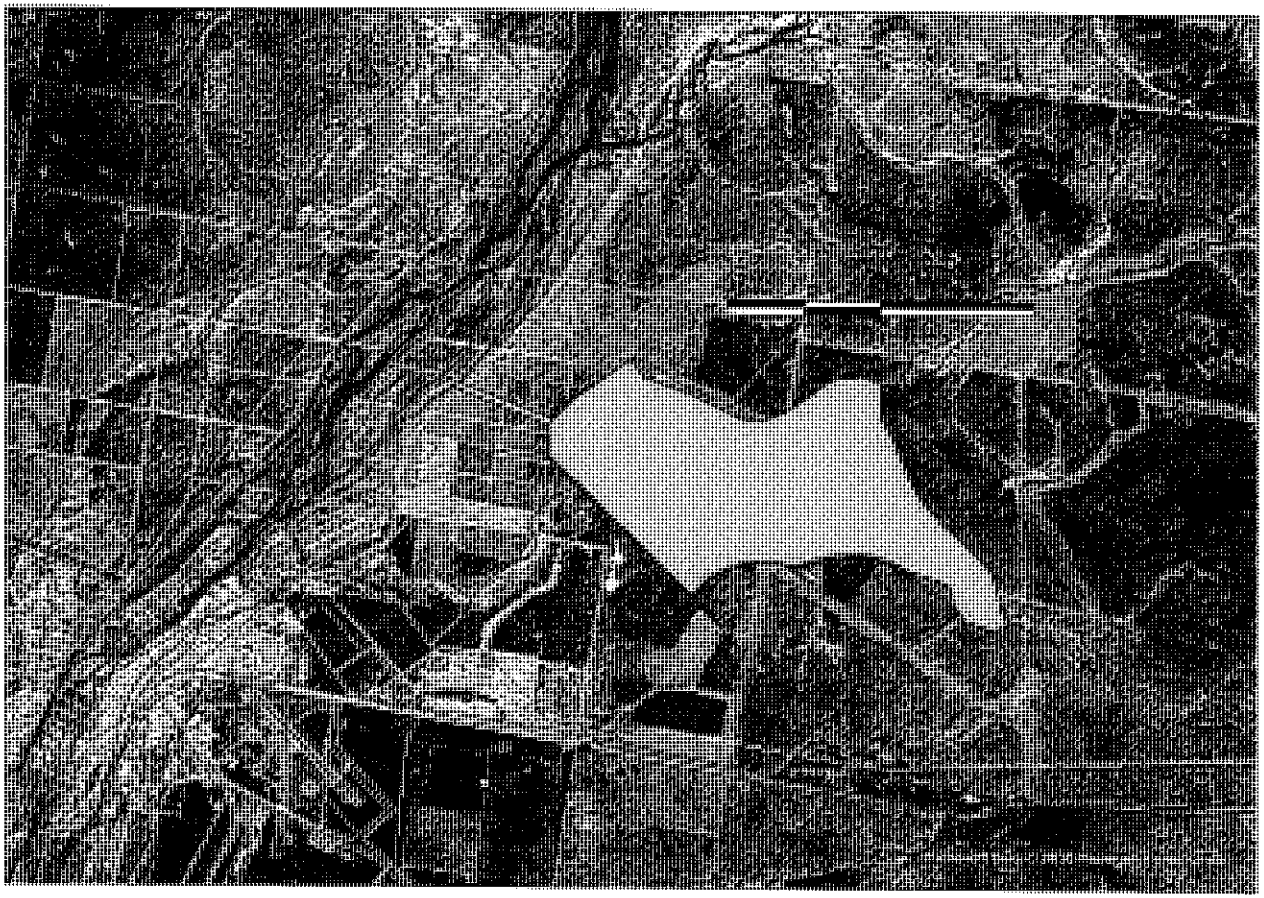

Figure ES2 Concept Design - Retarding Basin at Site 1

The retarding basin option also requires a reduced capacity diversion of Bradley's Gully, as it is unable to reduce flows sufficiently to completely eliminate flooding at the design flood (1% AEP or 100 year ARI).

Given the above, and the similarity of the estimated costs for the diversion and retarding basin options, we conclude that either of these proposals can form the basis of a viable flood mitigation scheme for Bradley's Gully and that both warrant further consideration in the detail study.

There is a greater risk of cost escalation with the retarding basin option as the cost estimates have assumed that material close to the site will be suitable for the construction of the embankment dam. This risk is lower with the diversion options as a relatively small amount of material is required for the construction of levee banks adjacent to the diversion channel.

The final choice will depend on Council's attitude to the various advantages and disadvantages of these options, and their relative risks.

In respect of the other issues, namely the Charleville Levee and Warrego River issues, these require further assessment as part of the proposed detail study. The requirements for the detail study are included in our recommendations.

Recommendations

Long Term Flood Mitigation Solution for Bradley's Gully

The recommended long term solution to flood mitigation in Bradley's Gully, subject to confirmation in the detail study, comprises:

EITHER:

a) Construction of a retarding basin (site 1) on Bradley's Gully (as shown in **Figure 27**);

b) Extending the existing levee from Hunter Street to the Gully together with a small diversion weir in order to throttle the through flow in the gully (recommended for inclusion in of the short term works if funding allows); and

c) An improved culvert crossing of Bradley's Gully at Deverill Street to allow access during flood periods to improve internal movement in the town.

OR:

d) A diversion weir and 100m base width diversion channel from Bradley's Gully (Option B) utilising the Erbacher Road reserve.

Short Term Works

The immediate works proposed in the *Interim Report* comprise removal of a section of the levee east from Hunter Street to re-open the Bradley's Gully breakout flow path, to be replaced by a temporary system which can be removed should the Gully be in flood while the river is not, but still provide protection against a Warrego River flood. Alternatively, this could comprise a significant increase in the piped drainage through the levee at this point.

At the time of writing the *Interim Report*, we envisaged that this would be sufficient, on its own, to provide some relief from the problem in March 2010 when the levee prevented this breakout from operating.

However, subsequent 2D modelling has shown that this alone will not be very effective and requires throttling of the Gully flow to make it more effective. The latter requires extending the existing levee from Hunter Street to the Gully together with a small diversion weir in order to throttle the through flow in the gully.

If the latter cannot be funded in the short term, these works should be included as part of the long term solution if the retarding basin option is adopted.

Long Term Flood Mitigation Solution – Warrego River
The Charleville levee was to be constructed in two stages, only the first of which has been implemented. The second stage was designed to increase the flood immunity from that of the 1997 flood to that of the 1990 flood. We recommend that this be revisited in the proposed detail study together with its construction requirements.

In addition to hydraulic modelling, we recommend that an audit of the existing levee be undertaken to:

- Confirm the structural integrity of the earth and concrete sections of the levee;
- Facilitate the design of the stage 2 raising; and
- Make recommendations for its ongoing maintenance.

We also recommend that the hydraulic modelling component of the detail study includes:

- Northwards extension of the levee to provide protection to the properties along Banjarra Drive;
- Investigation into the efficacy of increasing the cross drainage waterway area in the Mitchell Highway embankment in reducing upstream flood levels;
- Investigation into the efficacy of reopening the Warrego River flood channel closed off by the Augathella Road in reducing upstream flood levels; and
- Investigation into hydraulic effectiveness of clearing some of the sand accumulated in the Warrego River. It should be noted, however, that any such clearing is likely to have only a temporary effect whilst significant amounts of sand are moving along the river as appears to be the case. This sand is a product of natural erosion exacerbated by land clearing and grazing.

If the detail study is to consider this possibility, it is also recommended that an investigation of sediment transport is included in order to evaluate the long term effectiveness of sand removal.

The detail study should make recommendations for the long term flood mitigation in Charleville from the Warrego River, and if raising of the levee is recommended, construction requirements should be included.

The detail study should also include consideration of flooding from extreme floods, in excess of the design capacity of the flood mitigation works.

Requirements for Detail study
The body of the report contains recommendations in respect of the items to be included in the detail study to enable design of the proposed works together with further investigations into the long term flood mitigation options for the Warrego River.

Provisional Action Plan
A provisional action plan with approximate timings has been developed and is given in **Table ES3**. It should be noted that the timing is very dependent on the availability of funding for the project, and assumes that funding for the Bradley's Gully flood mitigation works will be available by October 2010 and for any subsequent Warrego River flood mitigation works by October 2011. Any delays in funding will result in a subsequent delay in the action dates.

Estimated Cost Summary – Recommended Works
Table ES4 summarises the estimated costs of the recommended works. As indicated above, the estimated costs are preliminary and subject to confirmation at subsequent stages of the project.

The costs of long term flood mitigation works for the Warrego River are not included at this time as these are dependent on the outcome of the proposed detail study.

Table ES3 Provisional Action Plan

Action	Description	Action by	Action due by end
Short Term flood mitigation Bradley's Gully	Appoint Consultant	MSC	Aug 2010
	Design	Consultant	Oct 2010
	Construction	MSC/Contractor	Dec 2010
Long term flood mitigation Bradley's Gully	Prepare brief/appoint consultant	MSC	Oct 2010
	Hydrologic & Hydraulic Modelling	Consultant	Mar 2011
	Detail design	Consultant	May 2011
	Approvals	MSC	Jun 2011
	Construction /construction supervision	Consultant & contractor	Dec 2011
Long term flood mitigation Warrego River	Hydrologic & Hydraulic Modelling	Consultant	Oct 2010
	Funding Application	MSC	Aug 2011
	Detail design	Consultant	Mar 2012
	Approvals	MSC	Jun 2012
	Construction /construction supervision	Consultant & contractor	Dec 2012
MSC – Murweh Shire Council			

Table ES4 Estimated Costs of Recommended Works

Item	Estimate Costs $ Million
Short Term Flood Mitigation Works - Bradley's Gully Improved drainage or simple gates to levee near Hunter Street	0.15
Detail study including hydrologic & hydraulic model studies, levee audit and geotechnical studies (but excluding detail design which is included in works estimates)	0.5
Long Term Flood Mitigation Works - Bradley's Gully: a) Retarding Basin at Site 1, Diversion weir/levee, improved Deverill Street Crossing OR Diversion Option B	22.5 20
TOTAL	**20.7-23.2**
NOTES: 1. All quoted costs are exclusive of GST 2. Costs of long term flood mitigation from Warrego River are not included	

1 Introduction

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It should be noted that this commission has regard principally to structural flood mitigation measures, and that others are responsible for non-structural approaches to reducing future flood impacts.

1.1 Initial Study Objectives

The principal objectives of the Initial Study, as stated in the Initial Brief, are to:

- Consult widely with the community and obtain submissions from interested community representatives on possible mitigation strategies for Bradley's Gully;
- To analyse all submissions and evaluate and prioritise feasible and acceptable mitigation solutions;
- In conjunction with existing studies, flood modelling plans and acceptable submissions to identify and evaluate and provide expert advice on all flood mitigation options for the Gully; and
- Provide prioritised recommendations for all viable and cost effective options available for the mitigation of further flooding events occurring as a result of heavy rainfall in the catchment of Bradley's Gully.

1.2 Scope of Work

The following Scope of Work was adopted to meet the objectives of the Initial Study:

- Seek submissions from the community in respect of potential mitigation strategies for Bradley's Gully;
- Summarise, evaluate and prioritise submissions received;
- Liaise with relevant agencies to obtain information regarding recent floods in Charleville;
- Collate flood level records from the March 2010 floods and critically compare to previous modelling;
- Collate and tabulate flood level records from previous floods;
- Collate rainfall data from within or adjacent to the Bradley's Gully catchment for the recent flood;
- Undertake hydrologic modelling for the Bradley's Gully catchment to a level commensurate with the data available in order to estimate peak flood flows and volumes for a range of flood probabilities;
- Identify any potential flood mitigation storage sites from mapping and field work, and estimate their flood mitigation efficacy with the hydrologic model;
- Undertake appropriate, preliminary hydraulic analysis or modelling of potential flood mitigation options to the extent required to determine whether these are of sufficient merit to warrant inclusion in the detail study. The scope of this component was extended subsequent to submission of the Interim Report to include limited 2D hydraulic modelling to allow the threshold flood flows through Bradley's Gully to be better defined;
- Carry out preliminary level estimates of costs for those measures considered to be worthy of further investigation together with listing of potential issues in their implementation;
- Investigate and evaluate a full range of potential structural flood mitigation options from submissions received and our own considerations;
- Summarise the investigation of potential structural flood mitigation options, and make recommendations for options worthy of further consideration in the proposed detail study together with priorities where appropriate;
- Report progress to Council and the Murweh Mitigation Group at appropriate points though the study period; and
- Prepare draft and final reports clearly setting out the work undertaken and the results there from with details of the outcomes from the community consultation and technical studies in suitably structured appendices.

1.3 Structure of this Report

The following chapters of this report are structured as follows:

- Summary of 2010 and other recent floods;
- Community consultation and summary of submissions received;
- Hydrologic and hydraulic modelling;
- Evaluation of potential flood mitigation options;
- Other flood related issues; and
- Recommendations.

1.4 Acknowledgements

The assistance of Murweh Shire Council officers and staff, and of the members of the Murweh Flood Mitigation Group is acknowledged, as is the interest and input of the general public during the community consultation phase of the study.

1.5 Limitations Statement

The sole purpose of the services performed by Sargent Consulting was to undertake an Initial Flood Mitigation Study for Bradley's Gully and provide a report in accordance with the scope of services set out in the agreement between Sargent Consulting and Murweh Shire Council. That scope of services was defined by requests of Council, by the time and budgetary constraints, and by the availability of appropriate data.

In preparing this report, the Sargent Consulting has relied upon, and presumed accurate, certain information (or absence thereof) in respect of survey and other data provided by Council , rainfall and streamflow data provided by government agencies and others identified herein. Except as otherwise identified in this report, Sargent COnsulting has not attempted to verify the accuracy or completeness of any such information.

No warranty or guarantee, whether express or implied, is made with respect to the data reported or findings, observations, conclusions and recommendations expressed in this report. Further, such data, findings, observations, conclusions and recommendations are based solely upon existing available survey, rainfall, streamflow data and any such information as identified in the report.

The report has been prepared on behalf of and for the exclusive use of Murweh Shire Council and is subject to and issued in connection with the provisions of the agreement between the Sargent Consulting Council. Sargent Consulting accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

2 Flooding in Charleville

2.1 Location

Charleville is located on the left (south) bank of the Warrego River some 750km west of Brisbane and 200km north of Cunnamulla. **Figure 1** shows the location of the Warrego River catchment. The Warrego River is a tributary of the Darling River and hence part of the Murray-Darling Basin. Its location within the Murray-Darling Basin is shown in **Figure 2**. **Figure 3** shows a more detailed map of the Warrego River catchment.

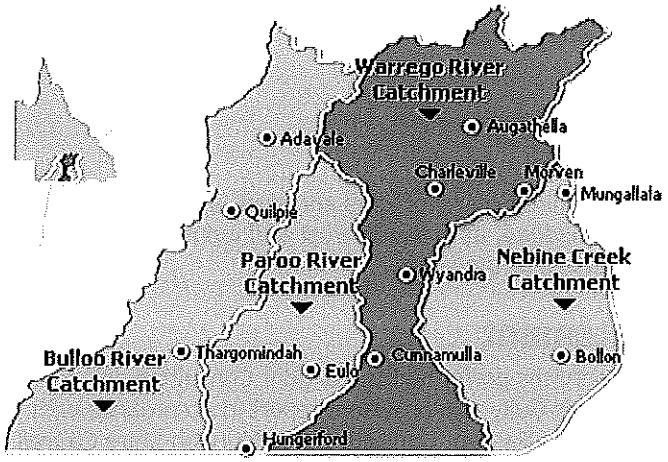

Figure 1 Location Plan
Source: South West NRM website

Figure 2 Murray Darling Basin Map
Source: MDBA website

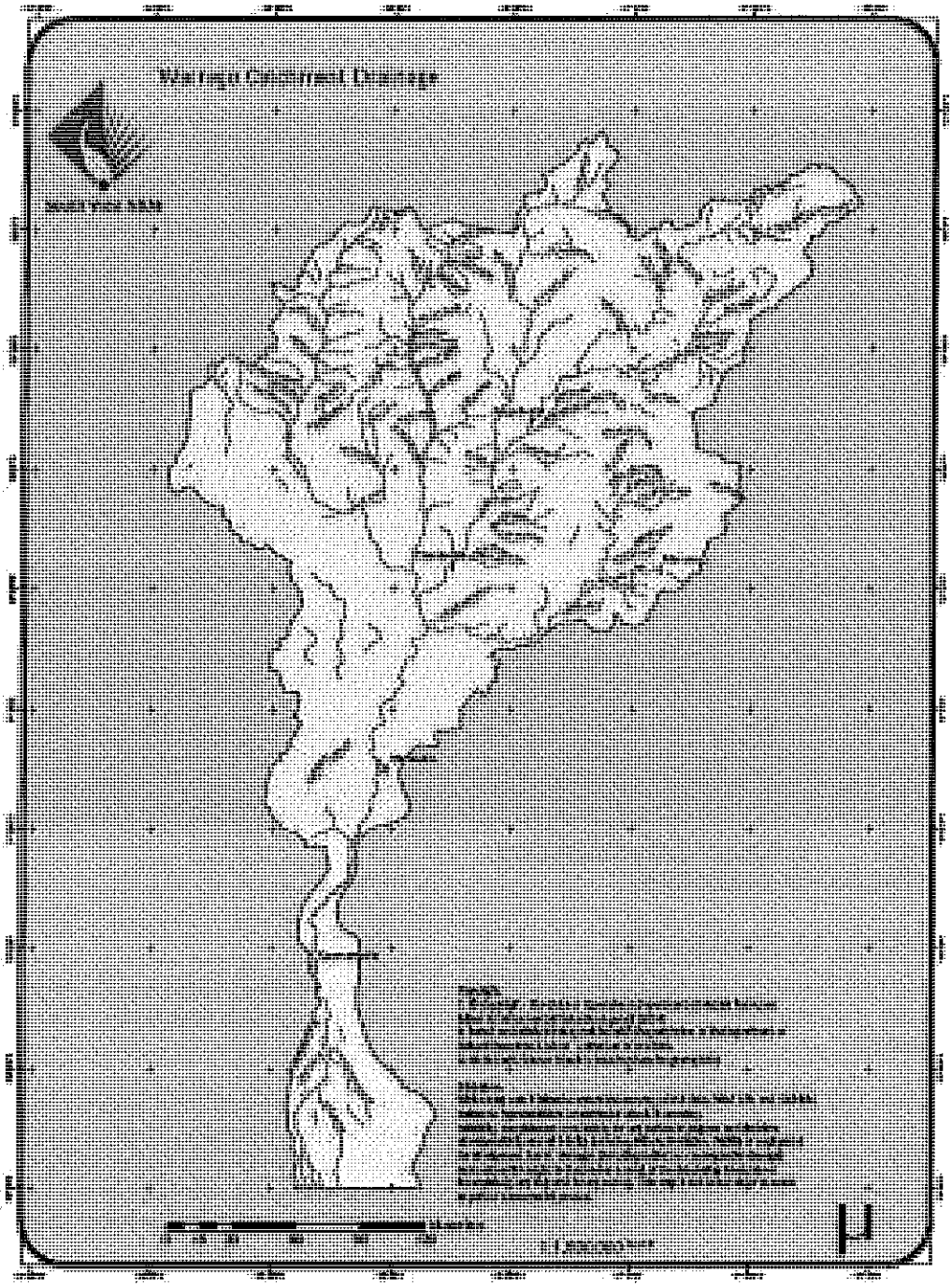

Figure 3 **Warrego River Catchment**
Source: South West NRM website

Bradleys Gully is a left (east) bank tributary of the Warrego River which it enters about 6km downstream of Charleville. At Charleville, the catchment area of the Warrego River is 16,600km^2, whilst that of Bradleys Gully is about 310km^2. The catchment area of Bradley's Gully is shown in **Figure 4**.

Figure 4 Bradley's Gully Catchment
(Base Map Source: Google Earth)

2.2 Flooding in Charleville

An important feature in the interaction of flood flows between Bradley's Gully and the Warrego River is the way in which these two watercourses run roughly parallel through Charleville. This is shown in **Figure 5**.

The whole town of Charleville is built in the Warrego River floodplain and from where Bradley's Gully enters the Warrego floodplain it is essentially an anabranch of the Warrego. There is natural interaction between the two watercourses depending on the relative level in each. In Warrego River floods, overbank flow occurs near Kennedy and Hilda Streets and once over the natural levee forming the bank, the breakout flow makes its way to Bradley's Gully if it is at a lower level.

Conversely, when Bradley's Gully is in flood, it naturally overflows from a breakout near Burcher Street into the Warrego River near Hunter Street and Kennedy Street.

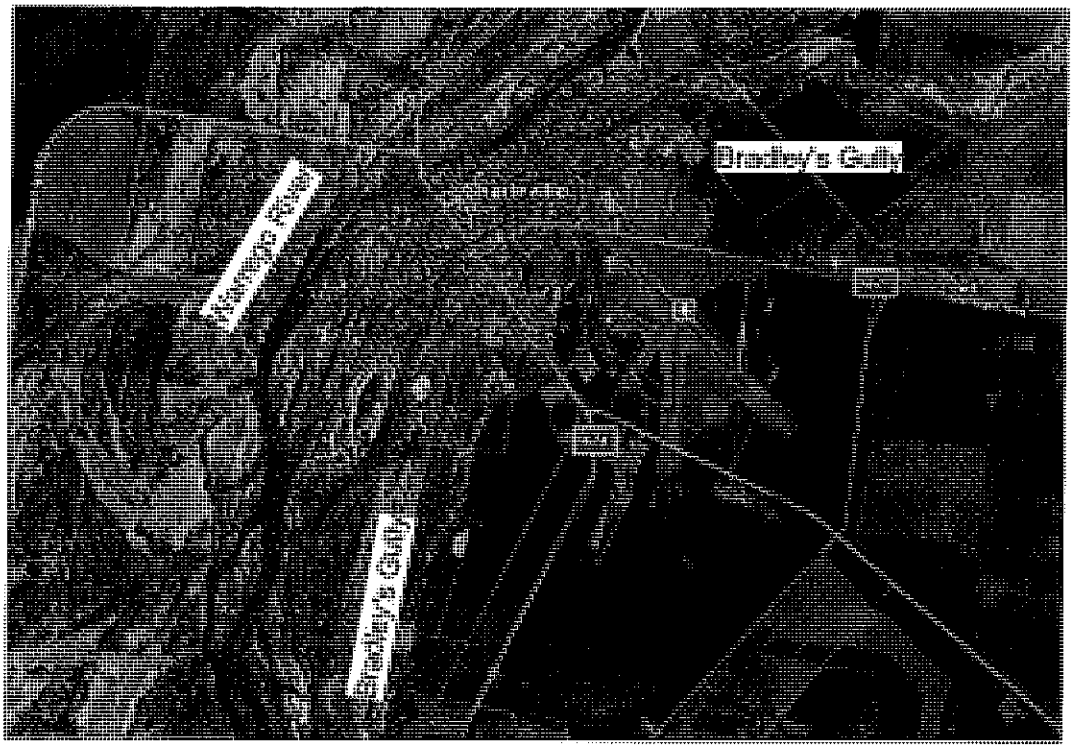

Figure 5 Warrego River and Bradley's Gully through Charleville
(Base Map Source: Google Earth)

2.3 Flood History

There have been many floods affecting Charleville since its gazettal as a town in 1868. Official records date from 1910, with the flood of record being in April 1990 when a flood height of 8.54m (296.3m AHD) was recorded on the town flood gauge. This was 1.58m higher than the previously recorded maximum of 6.97m in April 1956.

Anecdotal information suggests that a flood in 1890 was similar to the 1990 level but there is no known direct evidence of this.

Table 1 shows peak Warrego River flood levels since 1956.

Table 1 Peak Flood Levels Warrego River at Charleville

Date	Peak Flood Height m Gauge Height	Peak Flood Height m AHD
Feb 1956	6.55	294.3
Apr 1956	6.97	294.7
Apr 1990	8.54	296.3
Feb 1997	7.39	295.2
Jan 2004	5.29	293.1
Jan 2008	6.02	293.8
Mar 2010	6.65	294.4

Flood levels in Bradley's Gully have been recorded only since 2000. The peak level in March 2010 of approximately 4.2m (295.3m AHD) was the highest since records began and was 1.0m higher than the previous highest level of 3.2m (294.3m AHD) in Jan 2008.

It is worth noting that the peak level in Bradley's Gully in the March 2010 flood was 0.9m higher than that in the Warrego River.

2.4 Flood Mitigation

Scott & Furphy (1991) recommended construction of the Charleville levee and upstream diversion of Bradley's Gully following the 1990 flood to a level giving protection to a flood of that magnitude (after allowing for the level increase caused by the levee itself) with a freeboard allowance of 1m.

A more detailed design study by Kinhill Cameron McNamara (1993) refined the design but maintained the concept put forward in the 1991 report. After a space of several years a further design study was undertaken (Egis 2000) which again refined the design but with the same concept, and undertook geotechnical studies to identify suitable sources of material for constructing the levee.

The levee design was subsequently modified to be constructed in 2 stages: Stage 1 providing protection up to the 1997 flood level and with Stage 2 subsequently to provide protection up to the 1990 level. Presently, only Stage 1 has been constructed. Stage 1 did not include the Bradley's Gully diversion or the northern extension of the levee to prevent Bradley's Gully overflowing inside the levee.

The final design of the levee (Sudholz 200?) was based on a 2 stage construction. Stage 1 appears to have provided protection to about the 1997 flood level, with subsequent raising in Stage 2 to give protection to the 1990 level. Only Stage 1 has been constructed at this time. Although it was not possible to locate a copy of the final design report, a search of Council files and the levee tender documents have revealed the following:

- The levee was designed on the basis of protection against the 1997 flood (approx 1 in 80 AEP) plus 500mm afflux (understood to be from the combination of the levee itself and the Mitchell Highway crossing) plus a freeboard allowance of 300mm;
- The 300mm freeboard was subsequently deducted starting from section B (ie. Sections B to E) (undated Memo from CEO to Sudholz);
- Verbal information that the overflow structures such as at Hunter Street were also omitted, confirmed by site inspection.

2.5 Summary of 2010 Flood

The March 2010 flood was caused by a severe low pressure system originating within the monsoon trough over the Northern Territory on 22nd February 2010, moving over Queensland and causing widespread rainfall over a wide area, including the Warrego River catchment, in the first week of March.

The following extract from Bureau of Meteorology 2010 outlines the severity and spread of the rain:

An exceptional rain event affected central Australia, Queensland and far northern New South Wales during the last week of February and first week of March. The event began on the 22nd February, when a strong low pressure system developed over the Top End within the monsoon trough. The low tracked south through central Australia then east across southwest and southern Queensland before turning south again to cross the southwest Queensland border into northern New South Wales. The system produced heavy rainfall along its path causing widespread, record breaking flooding.

The most remarkable aspect of this event was the area covered by the heavy rainfall and the total volume of rainfall that fell. Daily rainfall totals exceeded 100 mm over 1.7% of Australia on the 1st March and 1.9% on the 2nd March. The latter is the largest area of 100 mm-plus daily totals on a single day in the Australian meteorological record, breaking the previous record of 1.7% set on the 22nd December 1956. The 2nd of March was the wettest day on record for Queensland with a state-wide average rainfall of 31.74mm, exceeding the previous record of 31.49mm set on the 21st of May 1981.

Figure 6 shows the extent of the rainfall across Australia for the week to 2nd March 2010,

Figure 3.2.1 Weekly rainfall across Australia to 9am on the 2nd of March 2010.

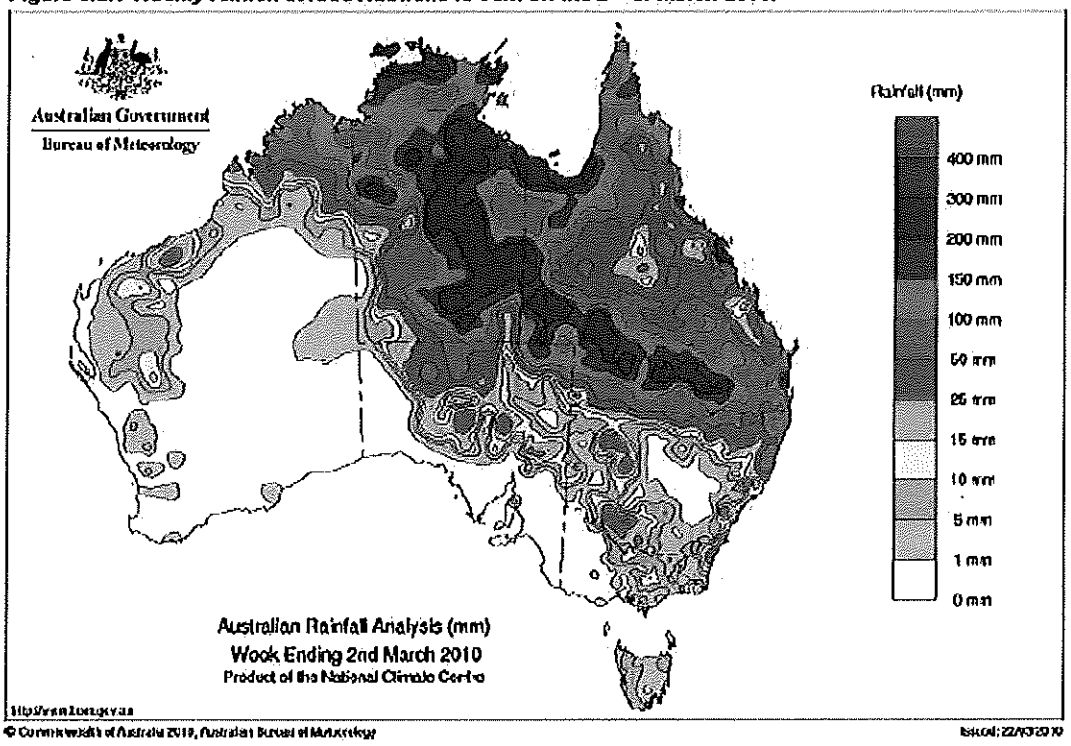

Figure 6 Rainfall across Australia Week to 2nd March 2010
Source: BOM (2010)

The Bradley's Gully flood was the result of rainfall of 250mm over the period 1st to 4th March 2010, 100mm of which fell in 8 hours from 5pm on 1st March. The maximum 1 hour rainfall was 20mm. Rainfall was widely distributed over the catchment with very similar totals being recorded at Charleville and at Raceview. This rain fell on an already wet catchment resulting in a relatively large proportion of runoff. Rainfalls in the Upper Warrego catchment were much less than around Charleville.

Figure 7 shows the cumulative rainfall from 28th February to 4th March at both Charleville and Raceview, and **Figure 8** shows hourly rainfalls over the same period.

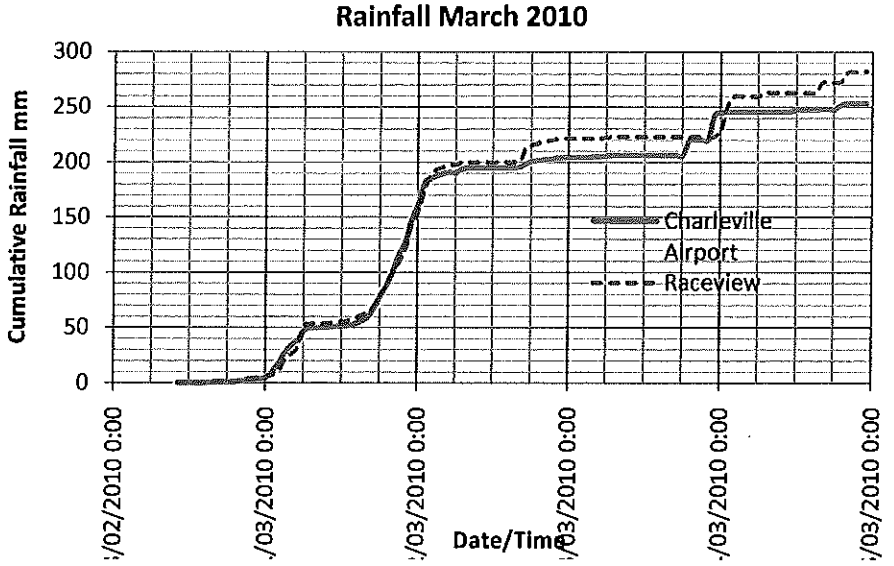

Figure 7 Cumulative Rainfall

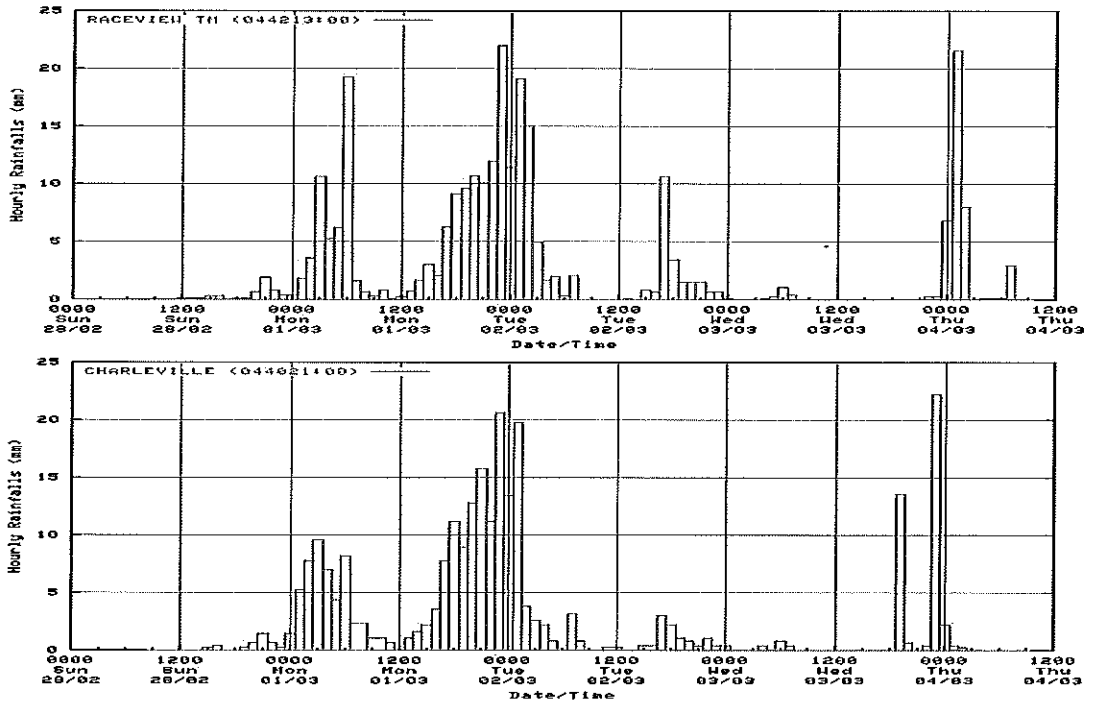

Figure 8 Hourly Rainfall Charleville and Raceview March 2010
Source: BOM (2010)

Figure 9 gives the rainfall intensity – frequency – duration (IFD) analysis carried out by the Bureau of Meteorology which shows that 6 hour rainfalls were about 20 year average recurrence interval (ARI) or 5% annual exceedance probability (AEP) at both Charleville and Raceview increasing to about 50 year ARI (2% AEP) for durations of 12 to 72 hours at Charleville and in excess of 50 year ARI for these durations at Raceview.

RAINFALL INTENSITY FREQUENCY DURATION ANALYSIS

LOCATION: 044213 RACEVIEW TM

Analysis of the rainfall for the 96 hours to Thu Mar 4 09:00:00 2010

Rainfall (mm)	Period Ending	ARI (years)
4	6 mins ending at 22:36:00 01/03/2010	< 1
6	6 mins ending at 22:36:00 01/03/2010	< 1
8	10 mins ending at 22:40:00 01/03/2010	1
17	20 mins ending at 22:40:00 01/03/2010	2-5
19	30 mins ending at 22:40:00 01/03/2010	1-2
22	60 mins ending at 22:50:00 01/03/2010	1-2
36	2 hours ending at 22:40:00 01/03/2010	2-5
55	3 hours ending at 01:10:00 02/03/2010	5-10
90	6 hours ending at 01:50:00 02/03/2010	20
132	12 hours ending at 02:50:00 02/03/2010	20-50
177	24 hours ending at 02:05:00 02/03/2010	50-100
216	48 hours ending at 20:00:00 02/03/2010	50-100
250	72 hours ending at 01:50:00 04/03/2010	50-100

RAINFALL INTENSITY FREQUENCY DURATION ANALYSIS

LOCATION: 044021 CHARLEVILLE

Analysis of the rainfall for the 96 hours to Thu Mar 4 09:00:00 2010

Rainfall (mm)	Period Ending	ARI (years)
22	60 mins ending at 23:00:00 03/03/2010	1-2
34	2 hours ending at 00:00:00 02/03/2010	2
63	3 hours ending at 01:00:00 02/03/2010	5
93	6 hours ending at 01:00:00 02/03/2010	20-50
131	12 hours ending at 03:00:00 02/03/2010	20-50
171	24 hours ending at 01:00:00 02/03/2010	50-100
200	48 hours ending at 20:00:00 02/03/2010	20-50
239	72 hours ending at 00:00:00 04/03/2010	50-100

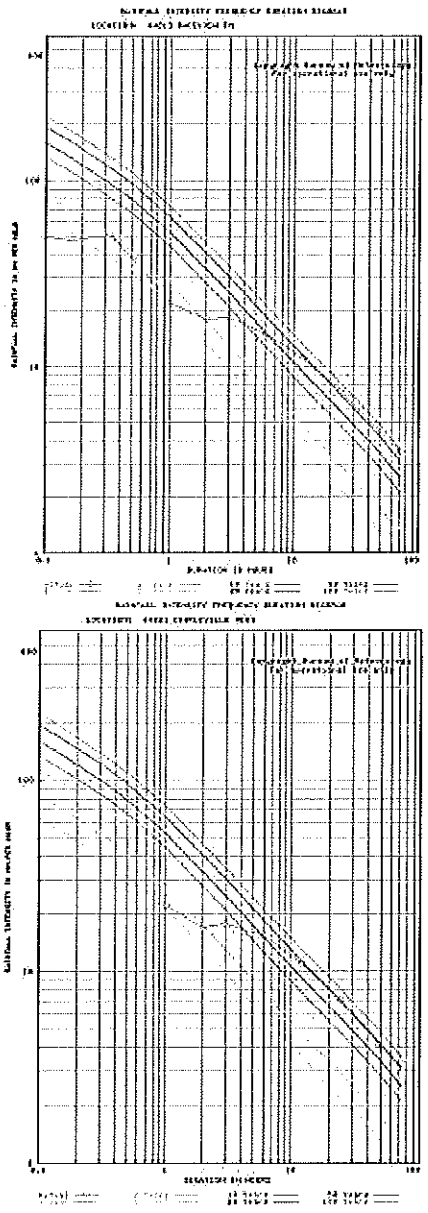

Figure 9 Rainfall IFD Analysis
Source: BOM (2010)

Water level hydrographs for the Warrego River and for Bradley's Gully at Charleville are reproduced from WRM (2010) in **Figure 10**. The Warrego River peaked at 6.65m (294.4m AHD) at about 5pm on 2nd March 2010. **This level would have resulted in overbank flooding in the absence of the levee, so the levee did fulfil its primary function in preventing this.**

Bradley's Gully peaked in Charleville at about 4.2m (295.27m AHD) (approximated as the maximum gauge board height of 4.0m was exceeded) between 11.30am and 2pm on 2nd March 2010.

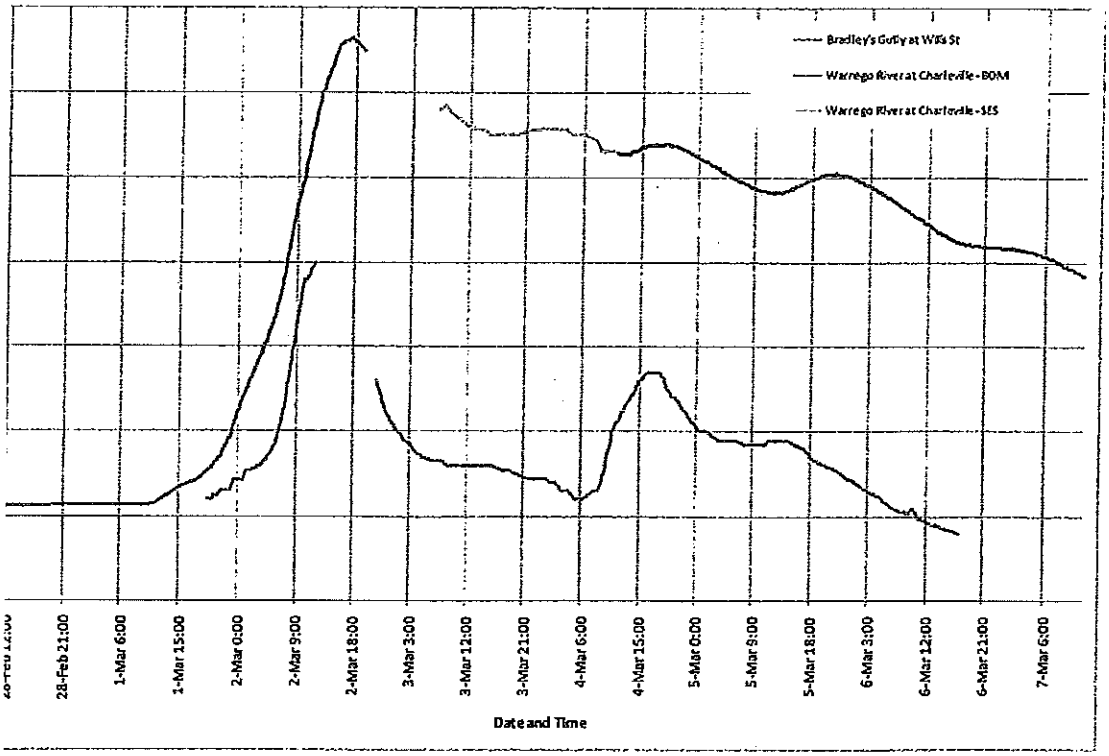

Figure 10 Warrego River and Bradley's Gully Flood Levels March 2010
Source: WRM (2010)

Preliminary results of the hydrologic model set up for this study (see **Appendix B**) indicate a peak flow in Bradley's Gully of approximately 1,000m^3/s, which was found to be about a 50 year ARI (2% AEP) flood, which is consistent with the rainfall probability.

Preliminary hydraulic computations showed the bankfull capacity of the town reach of Bradley's Gully to be only about 200m^3/s. This difference between peak flow and channel capacity is consistent with the degree of overbank flooding which occurred throughout the town reach.

The exclusion of the Bradley's Gully Diversion and the upstream return section of the levee from the Stage 1 scheme did not allow for the natural breakout which occurs from Bradleys Gully in the vicinity of Burcher Street back into the Warrego river near Hunter Street. The small diameter pipes constructed through the levee in the vicinity of Hunter Street are totally inadequate in catering for return of this overflow to the river, and were, presumably, designed to cater for local storm runoff only. Photographs taken by residents indicate that there was minor overtopping of the levee at this point (see Plate 1).

This resulted in the breakout flow being trapped behind the levee and turning south west to flow inside the levee. Some of this flow exited from behind the levee at the gap at the Mitchell Highway crossing and some flowed back into Bradley's Gully exacerbating flood levels.

The approximate location and route of this breakout is shown in **Figure 11.**

Plate 1 **Water just overtopping levee near Hunter Street**
NOTE: Lower Level in Warrego River

It is understood (WRM 2010) that a further breakout occurred from Bradley's Gully in the vicinity of Walter Street across the junction of Partridge and Well Streets, across the Warrego Highway and railway, across Hood Street and the Mitchell Highway, then returning to the Gully downstream. The approximate location and route of this breakout is shown in **Figure 12.** This breakout also occurred in the 1990 flood (and probably in the other recent floods)

It is possible that high water levels in the Warrego River downstream of Charleville where Bradley's Gully enters the river could have increased flood levels in the south west part of the town, but as residents reported high flow velocities in the Gully, this does not appear to have been a major factor.

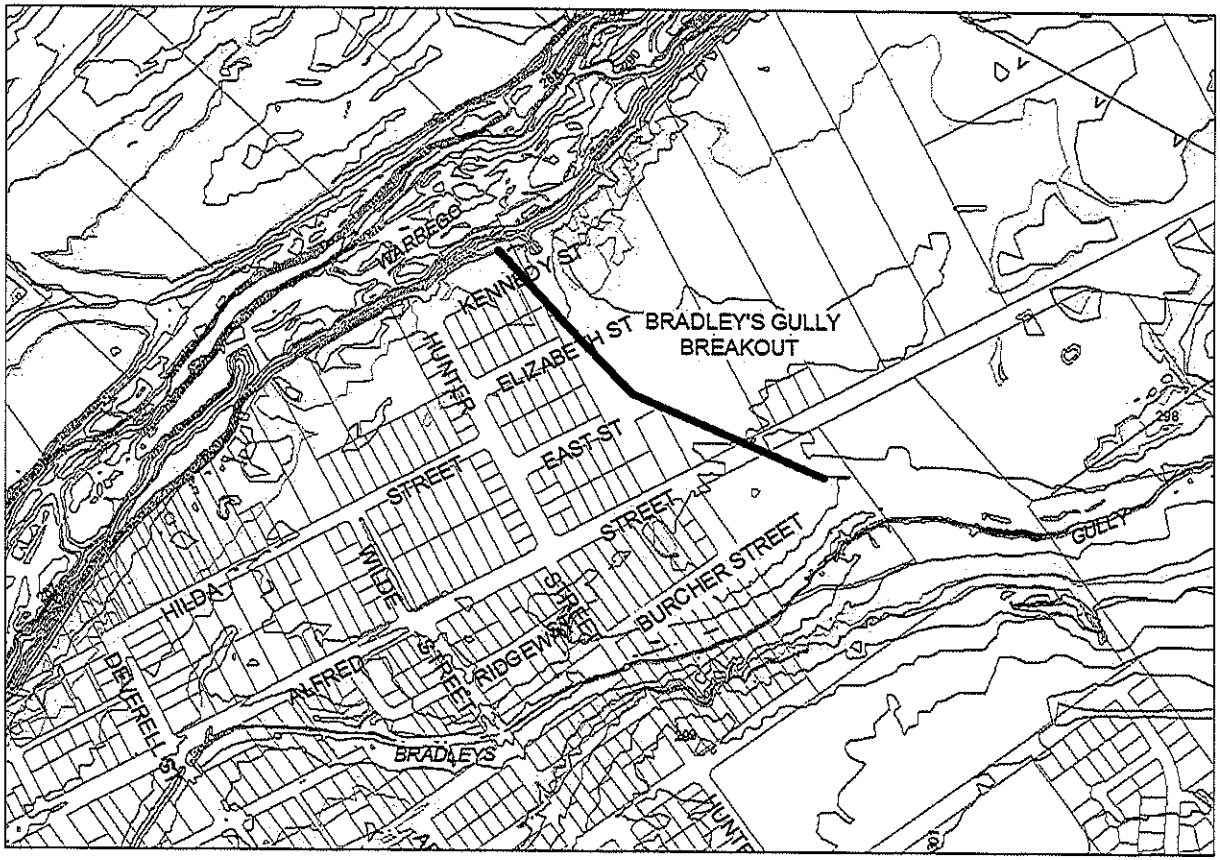

Figure 11 Bradley's Gully Breakout near Burcher Street

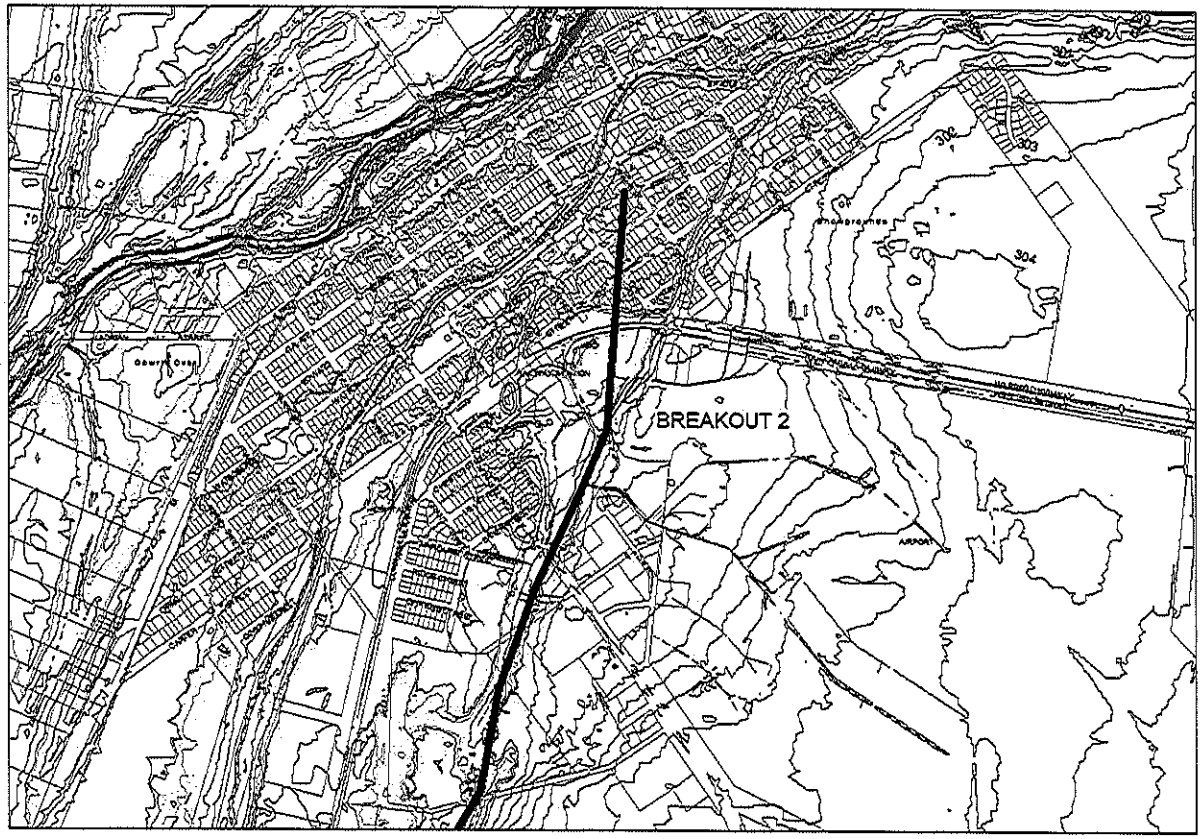

Figure 12 Bradley's Gully Breakout near Walter Street

3 Community Consultation

3.1 Submissions

Council provided accommodation for the consultants in the new Library Building in Alfred Street. This was a good location with direct street access. The consultation period ran from 11th – 21st May 2010 and was advertised prior to the arrival of the consultants through local radio and print media and the circulation of flyers through the business district. Further consultation continued after the formal period by telephone and by appointment.

Consultation was conducted on a personal basis with notes being taken of points raised. A pro-forma was also available for those who wished to provide information in this way. In all, a total of 41 submissions were recorded, excluding those who were merely enquiring about the current study. This included a submission from the Chamber of Commerce which itself includes a number of individual submissions resulting from a public meeting called by the Chamber on 23rd March 2010.

As Council is aware, there is a great deal of community feeling that the flooding issues in Charleville need to be resolved urgently, and that if there is another flood which causes widespread damage it will have serious consequences for the town's future; as many businesses could not sustain further loss. Also some residents have already relocated elsewhere and more would be likely to do so if flooded again.

3.2 Summary of Submissions

The 41 submissions received are summarised in **Appendix A** hereof.

Whilst primarily focussed on community suggestions for flood mitigation in respect of Bradley's Gully, a number of other issues were raised. In addition to the widespread concern regarding the recent floods, the issues and the suggested actions can be categorised as follows:

- Bradley's Gully - Diversion;
- Bradley's Gully – other flood mitigation;
- Charleville Levee;
- Warrego River;
- Flood warning, dissemination of warnings and evacuation; and
- General.

Table 2 summarises the submissions received according to the above classification, and gives the number of individual submissions containing that suggestion. **Table 2** shows these numbers in descending order of popularity in each of the classifications, and the following paragraphs expand on the key points.

Table 2 Summary of Community Submissions

Suggestions/ Proposed Actions	Number
Bradley's Gully - Diversion	
Diversion of Bradley's Gully to Warrego River upstream of the town (12 no location, 7 at Raceview, 2 further upstream)	21
Diversion of Bradleys Gully south to Angellala Ck/Fifteen Mile Ck	5
Diversion of Bradleys Gully across railway tracks near Morven Road	3
Diversion of Bradleys Gully across railway tracks near hospital	1
Multi-channel system with diversions/flood gates	1
Bradley's Gully - Other	
Deepen the Gully through town and/or downstream, clean out culverts and/or increase culvert sizes	11
Upstream flood mitigation storage	5
Raise houses flooded in 2008	2
Develop linear park	1
Plant trees in Gully - scouring will maintain depth.	1
Realign Gully crossing at Parry St	1
Provide industrial land for business relocation to higher ground	1
Levee	
Replace small drains through levee near Hunter St with floodgates or permanent pumps	8
Increase levee height to 1990 protection	3
Concerns with levee construction	3
Warrego River	
Clearing out the river channel (non specific)	6
removal of "The Island"	3
Increase waterway area in Mitchell Highway crossing	3
"Big River" submission	2
Reinstate former flood channel on right bank of Warrego R near Pretty Pines (cut off by Augathella Road)	1
Build check dams in Warrego/Neve Rivers	1
Flood Warning, Dissemination and Evacuation	
Flood Mitigation Plan, Flood Action Plan etc	2
Improve flood warning system (including signs, sirens) SMS	2
Improve flood operation preparedness	1
Increase SES volunteer numbers	1
Increase SES volunteer numbers	1
Improve public information	1
General	
Move the town	1

3.2.1 Bradley's Gully - Diversion

A total of 31 of the 41 submissions (75%) included diversion of Bradley's Gully: 21 of these related to diversion into the Warrego River upstream of Charleville; 5 refer to diversions south across the Warrego Highway into the Angellala Creek catchment, and 4 within Charleville. Of the 21 submissions including the diversion to the Warrego River 7 specified a diversion at Raceview, 2 further north with the remainder unspecified.

Two of the submissions provided information on the proposed diversion routes.

3.2.2 Bradley's Gully - Other

A total of 11 submissions (27%) included some form of widening/deepening of Bradley's Gully either though the town, or downstream of the town, or improvement to the current culvert crossings. This included 1 suggestion to increase the capacity of the Wills Street bridge.

Five submissions related to upstream flood mitigation storage; 2 for the raising of houses flooded in recent events; and 1 each for the development of the town reach of Bradley's Gully into a linear park; for planting trees along the Gully to provide a natural scouring mechanism; realignment of the Parry Street crossing; and the provision of industrial land to facilitate relocation of businesses. The house raising and land development suggestions are outside the scope of this study, and are reported herein for completeness.

3.2.3 Charleville Levee

The main issue raised in submissions regarding the levee were in respect of its failure to deal with the flood breakout from Bradley's Gully near Burcher Street which naturally flowed into the Warrego River near Hunter Street. The original design of the Levee (Scott & Furphy 1991, Kinhill Cameron McNamara 1993 and Egis Consulting 2001) all included diversion of Bradley's Gully into the Warrego River further upstream and with the levee continuing further north.

The levee design prepared by Egis (2001) was based on giving protection to a repeat of the 1990 Warrego River flood taking account of the increase in water level resulting both from the floodplain constriction caused by the levee and by the diversion of Bradley's Gully into the Warrego River, together with a freeboard allowance of 900mm.

The final design of the levee (Sudholz 200?), was based on a 2 stage construction. Stage 1 appears to have provided protection to about the 1997 flood level, with subsequent raising in Stage 2 to give protection to the 1990 level. The actual design parameters are unclear, as it has not been possible, at the time of writing, to find the Design Report and a copy is being requested from Sudholz.

The current levee represents the Stage 1 construction only and omitted the Bradley's Gully Diversion, had a reduced length of levee both upstream and downstream , and a protection level to the 1997 flood only.

The exclusion of the Bradley's Gully Diversion and the upstream return section of the levee from the scheme did not allow for the natural breakout which occurs from Bradleys Gully in the vicinity of Burcher Street back into the river. The small diameter pipes constructed through the levee in the vicinity of Hunter Street are totally inadequate in catering for return of the overflow to the river, and were, presumably, designed to cater for local storm runoff only.

This has resulted in the breakout flow being trapped behind the levee and turning south west to flow inside the levee. Some of this flow exited from behind the levee at the gap at the Mitchell Highway crossing and some flowed back into Bradley's Gully exacerbating flood levels.

The main issue which has been raised in the community consultation is to allow for the discharge of the Burcher Street breakout flow back into the Warrego River. This requires the construction of a flood gate which can be open when Bradley's Gully only is in flood to facilitate the breakout flow, and closed when the Warrego River is in flood. There were a total of 8 submissions on this point (20%) one of which suggested permanent large diameter pumps in lieu of a floodgate with the same purpose.

The second issue in relation to the levee is the low level of protection it offers against Warrego River flooding, with 3 submissions requesting this be raised (and by implication extended) to provide protection to a 1990 level flood.

Three submissions expressed concerns regarding the actual construction of the levee. Our understanding is that the levee was constructed by Council's own labour force. This was undesirable as it does not separate the contractor/supervisor role that occurs in a traditional construction contract with supervision by a consulting engineer. The latter provides both a clear division of responsibilities and accountabilities which was lost by adopting direct labour construction.

Concerns were expressed in respect of the actual construction methods and materials used. These included:

- Lack of preparation of levee foundation – no stripping/stockpiling of topsoil;
- Omission of foundation "key" trench";
- Use of sub standard fill material (dispersive soils) which have poor characteristics when wet; and
- Inadequate compaction.

Concerns were also expressed in respect of the subsequent performance of the levee in the 2008 flood and of its maintenance. It was reported to us that one of the sections of concrete levee was undermined in 2008, and that reinstatement works were inadequate.

3.2.4 Warrego River

In total there were 9 submissions (22%) regarding cleaning out of the river channel: 6 of these were not specific and 3 referred specifically to removal of "The Island". We understand that DERM has rejected this possibility.

There were also 3 submissions (7%) calling for additional waterway area in the Mitchell Highway embankment these residents noting that the new bridge/embankment has a damming effect and resulting in an increase in upstream flood level; this increase lessens when the bridge/embankment are overtopped.

Two residents referred to the "Big River" submission which we understand had some specific proposals for sand removal from the river. To date, we have not been able to locate a copy of this submission.

One resident noted that the Augathella Road blocks off a natural flood channel near "Pretty Pines", and suggests bridging this to reopen it would result in some reduction in peak flood levels in the Warrego River.

One resident suggested a number of "check dams" be built in the Upper Warrego and Neve Rivers to

provide some attenuation of peak flows and hence lower flood levels.

3.2.5 Flood warning, dissemination of warnings and evacuation

Two submissions called for improvements to flood response planning in the form of a Flood Mitigation Plan, a Flood Action Plan and a Flood Etiquette Plan (assumed to refer to flood operations procedures).

A total of 5 submissions called for improvements to the flood warning system and/or to the means of disseminating this information to residents. The suggestions included:

- Additional telemetered rainfall and creek level stations in the Bradley's Gully catchment;
- Electronic signs at all town entry points and at a point in the CBD showing current and forecast levels;
- A single agency providing flood level and flood forecast information;
- Improved communication with the public;
- Improved evacuation procedures;
- Improved operational procedures; and
- Increased SES volunteer numbers and appropriate training thereof.

3.2.6 General

One suggestion to move the town.

4 Hydrologic and Hydraulic Modelling

4.1 Hydrology

A RORBWin hydrologic model was set up for the Bradley's Gully catchment, details of which are given in **Appendix B** hereof.

The Bradley's Gully catchment area was found to be 314km^2 which is significantly greater than the 220km^2 used in previous studies. This probably results from the better topographic data now available. A substantial part of the total catchment is south of the Warrego Highway and this may not have been appreciated previously.

The model was used to estimate peak flood flows for a range of event probabilities and for the March 2010 flood as given in **Table 3**. The latter was estimated to be 1,000m^3/s which is equivalent to a 50 year ARI (2% AEP) event. This is consistent with the rainfall probabilities.

Table 3 Estimated Design Flows in Bradley's Gully in Charleville

Average Recurrence Interval (ARI) Years	Annual Exceedance Probability (AEP)	Estimated Peak Flow m^3/s	Critical Storm Duration Hours
50	1 in 50 (2%)	1,000	6
100	1 in 100 (1%)	1,200	6
200	1 in 200 (0.5%)	1,400	6
500	1 in 500 (0.2%)	1,700	6

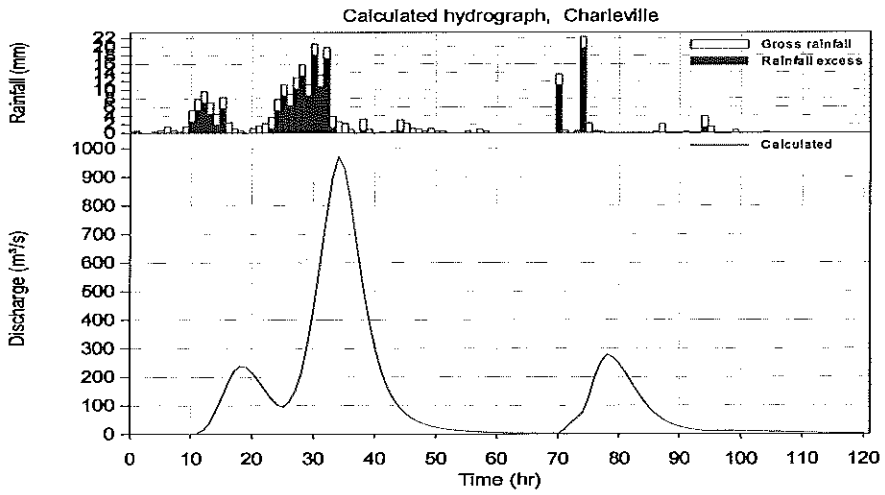

Figure 13 Bradley's Gully - Estimated Flow Hydrograph March 2010

The model has been used for existing conditions and to evaluate the effectiveness of the identified retarding basin sites.

Table 4 shows a comparison of the above flow estimates to those in previous studies. The estimates from the current study are higher than the previous studies, mainly as a result of the increased catchment area evident from recent topographic data.

Table 4 Comparison of Estimated Bradley's Gully Design Flows

Source	50 Year ARI (2% AEP) Peak Flow m^3/s	100 Year ARI (1% AEP) Peak Flow m^3/s
Current Study	1,000	1,200
Cameron McNamara (1973)	240	
Kinhill Cameron McNamara (1993)	870	1,000
Egis (2000)		570

4.2 Hydraulic Modelling

Limited 2D modelling was added to the Scope of Work of the Initial Study following the submission of the *Interim Report* in order to better quantify the flooding threshold flow through the town reach, which is an important element in the development of flood mitigation options. The model was also subsequently used to test the hydraulic efficiency of the various diversion options.

The modelling undertaken is outlined in the following paragraphs.

4.2.1 Model Setup

The hydrodynamic model XP-SWMM was used which allows a combination of 1-dimensional (1D0 and 2-dimensional (2D) flow elements. This model uses the TUFLOW model for its 2D components.

1D flows are flows in which conditions change generally in one direction only, such as in pipe flow or simple open channel flow, whereas 2D flows vary both along the channel and across the channel and are typified by flows in complex floodplains.

In a 1D hydrodynamic model, the flow path geometry is defined as a series of cross-sections so flow paths need to be pre-determined, whereas a 2D model uses a 3D model of the ground surface known as a digital elevation model (DEM) or digital terrain model (DTM) and defines the flow paths internally.

2D models are the current state-of-the-art for the modelling of complex floodplain flows.

The model was setup using the 1m contours which were obtained by photogrammetry for the levee investigation study (Egis 2000). The Charleville levee was added to the model using a recent survey of the levee crest levels provided by Council. 1D elements have been included to represent the Wills Street Bridge, the railway culverts and the levee drain near Hunter Street. The low level culvert crossings throughout the town have not been specifically included but are taken into account by the ground levels. As these are of such small capacity, this is not a significant issue.

The model was set up with a 2D grid size of 15m which represents a reasonable compromise between level of detail and model run time.

As the model was to be used to investigate Bradley's Gully flows only, no attempt was made to model concurrent Warrego River flows.

The basic model layout is shown in **Figure 14.**

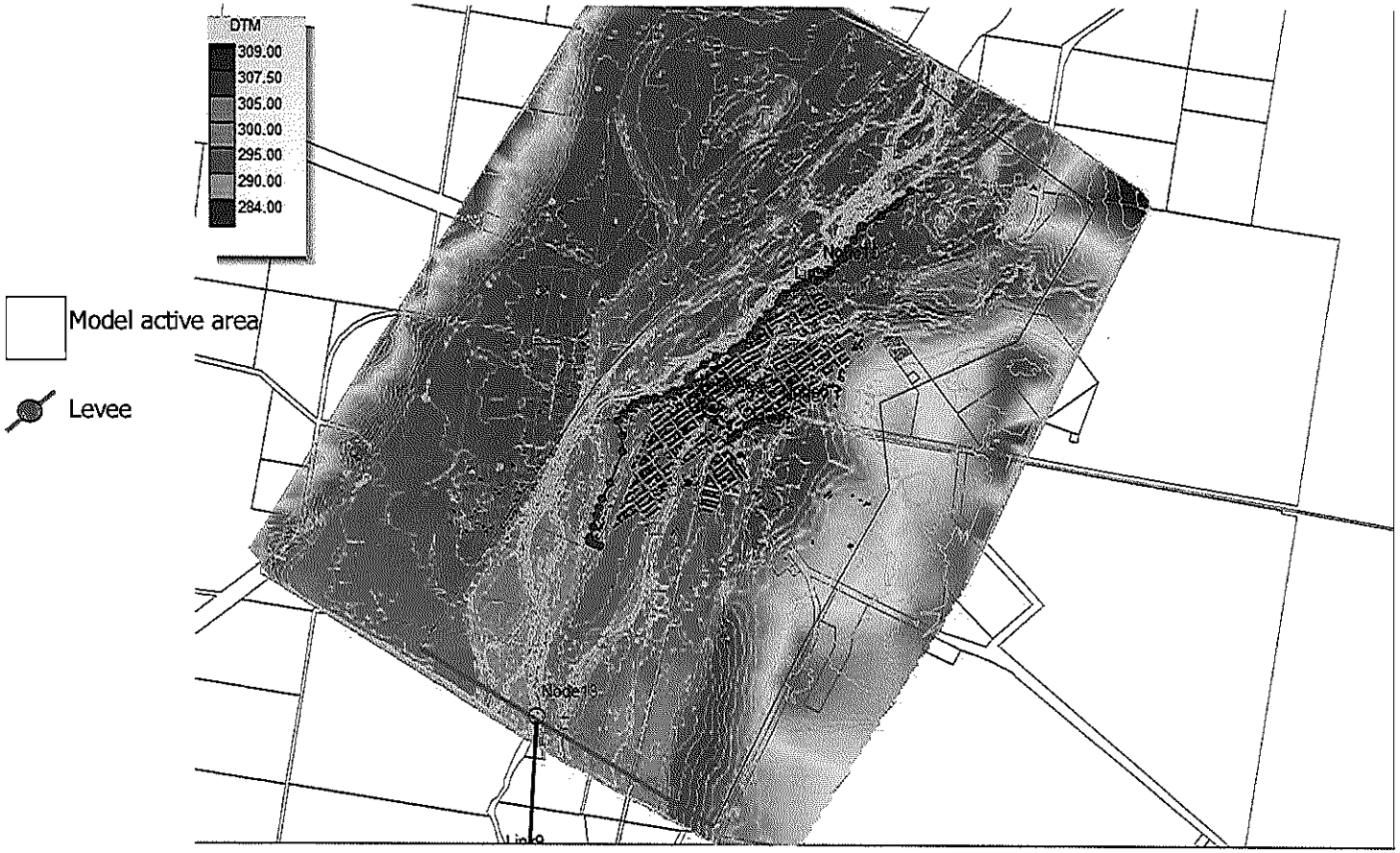

Figure 14 2D Model Layout

4.2.2 Modelling March 2010 Flood

The model was run for the March 2010 flood using the flow hydrograph estimated from the RORB model as shown in **Figure 13.** Comparing **Figure 13** with **Figure 10** there are some differences in shape and timing but these did not affect the purpose of the model, which was to establish the flows at which property flooding commenced.

The model was setup with hydraulic roughness (Manning's *n*) of various flow elements estimated from typical values and experience as given in **Table 5.**

Table 5 Adopted Hydraulic Roughness Values

Hydraulic Roughness Element	Adopted n value
Creek channel	0.03
Urban areas	0.08
All other areas	0.04

These values were found to give good agreement with the peak flood level at the gauge upstream of Will's Street with a modelled level of 295.3m AHD compared to the observed level of approximately 295.27m AHD..

Figure 15 shows the modelled flood extent at the time when the flow first reached the back of the levee near Hunter Street, from which is can be seen that a significant number of properties were already flooded by that time. Up to this point the lack of drainage through the levee had no influence on flood levels, so those properties would have flooded in any event.

The model was used to determine the flows at which property flooding commenced at a number of points through the town, as listed in **Table 6.**

Table 6 Threshold Flood Flows

Location	Threshold Flow m^3/s
Ridgeway Street	55
Alfred St/Hunter St	63
Wills Street	77

Compared to the estimated March 2010 peak flow in Bradley's Gully of 1,000m^3/s, these threshold flows are extremely low. Hence, in order to be effective, the proposed flood mitigation works must be able to reduce the flow through the town to about a 50m^3/s maximum under design flood conditions.

4.2.3 Modelling of Design Floods

The 2D model was subsequently modified to estimate the effectiveness of the various diversion options and the retarding basin option, and these model runs are reported upon in the relevant paragraphs of Section 5 where the individual options are considered.

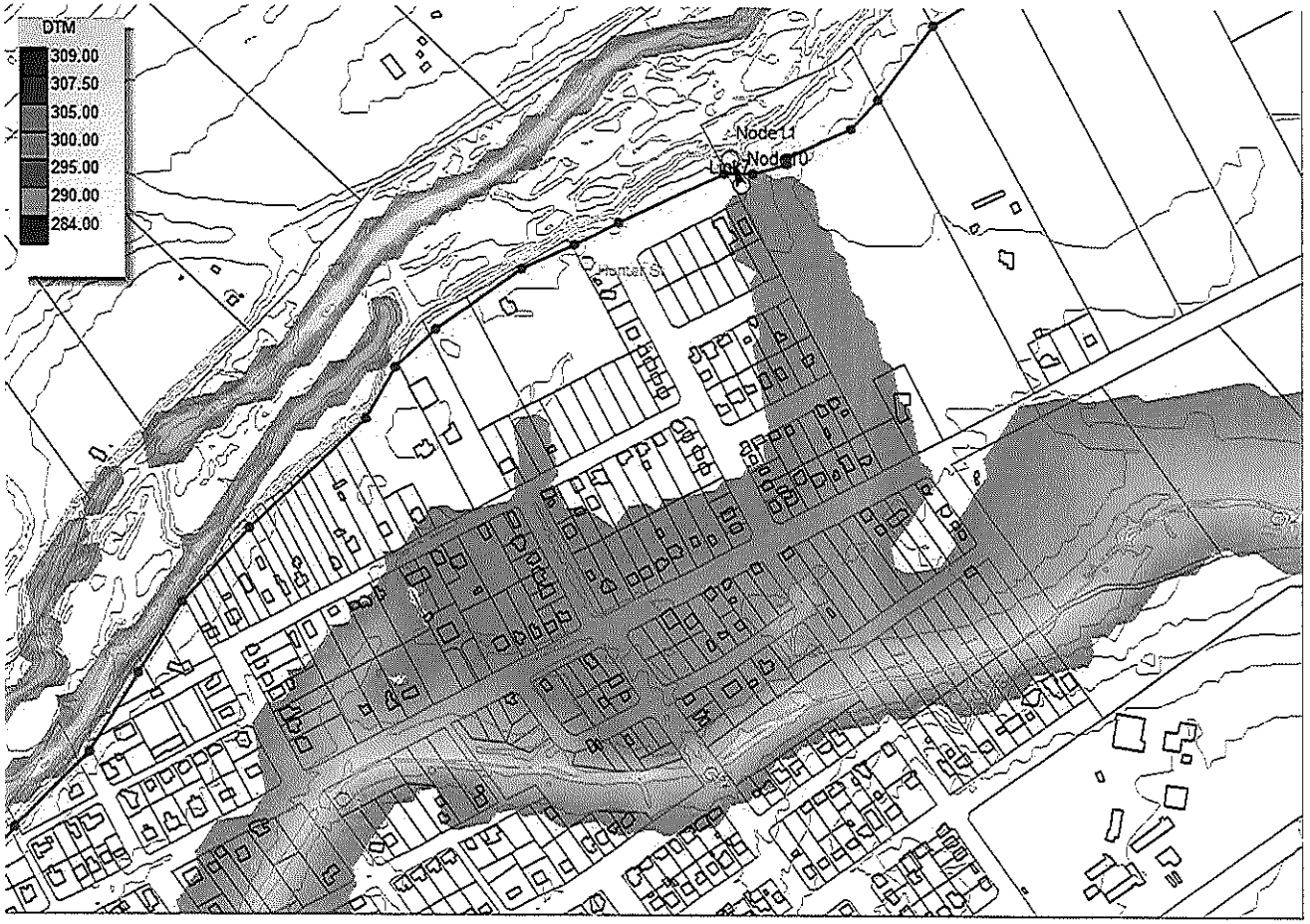

Figure 15 March 2010 Flood – Modelled Flow first reaching levee near Hunter Street

Figure 16 March 2010 Flood - Model Output at Maximum Level

5 Option Evaluation

Flood mitigation options both from community submissions and from our own technical considerations have been categorised as follows:

- Bradley's Gully - Diversion;
- Bradley's Gully – other flood mitigation;
- Charleville Levee;
- Warrego River;
- Flood warning, dissemination of warnings and evacuation; and
- General.

Of these categories, only the first four fall within the Scope of Work of the current study, and brief comments on these are given in the following paragraphs.

The evaluation was undertaken on the primary criterion of providing protection against a flood of 1% annual exceedance probability (AEP) (also referred to as 100 (1% AEP) Average Recurrence Interval (ARI)) which is the usual design criterion adopted in Australia. The 2010 flood was about 2% AEP (50 year ARI), so this design flood is more extreme than that which occurred this year.

It must be recognised however, that there is a 1% chance of this flood being exceeded each year, so a larger flood will occur at some time in the future. Whilst such a flood will result in some flooding, it will be much reduced compared to current flooding if the proposed works are constructed. It is important that the proposed works are resilient in the event that their design capacity is exceeded. This aspect has been considered only qualitatively in this Initial Study, but should be considered in more detail in the detail study.

5.1 Bradleys Gully Diversion

A number of potential diversion routes have been identified in the submissions and from the contours. These fall into the following sub-categories:

- Diversion to the Warrego River upstream of Charleville;
- Diversion of breakout flows within Charleville;
- Diversion downstream of Charleville to shorten return path to Warrego River; and
- Diversion south into the Fifteen Mile Creek/Angellala Creek catchment.

5.1.1 Diversion to Warrego River Upstream of Charleville

Five potential diversion routes (labelled A to E) from Bradley's Gully to the Warrego River upstream of Charleville are shown in **Figure 17**. Option E was omitted from the evaluation as it offers no advantages over D and being longer would be more costly to construct.

The hydraulic modelling (refer Section 4.2) has shown that flooding of properties in Charleville from Bradley's Gully commences at flows of only about $50m^3/s$, compared to the 1 in 100 AEP design flow of $1,200m^3/s$. Hence, in order to be effective, an upstream diversion would need to be able to convey $1,150m^3/s$ if designed for this flood immunity. As the flow estimates are of the order of

±10% accuracy at best, this should be rounded to the full design flow estimate of 1,200m^3/s.

In addition to the diversion channel, any scheme of this type will also require works to limit the flow continuing through the town reach of Bradley's Gully by means of a small diversion dam with low flow provision.

If the channel were unlined, it would be necessary to limit design velocities to less than 1.5m/s to avoid severe erosion unless adequate grass cover could be maintained when this could be increased to about 2m/s. Higher velocities would require protection of the bed and banks against erosion by either rock protection or a synthetic erosion protection system such as GEOWEB, either of which would substantially increase the cost.

At a practical maximum depth of 3-4 m, an unlined channel would need to be 200-300m in width in order to convey 1,200m^3/s. Even with rock lining, the channel would need to be of the order of 100m in width.

If the Warrego River is in flood at the same time as Bradley's Gully, the flow from the diversion will result in some increase in flood level in the river. This is discussed in Section 5.7 hereof. Also, with high water level in the river, the flow capacity of the diversion will be marginally reduced.

At any of the sites the inlet to the diversion must be at least as high as that of the levee at the point of entry to the Warrego River in order to prevent Warrego River flows entering Bradley's Gully by reverse flow up the diversion, when the latter is not in flood.

As a group, these potential diversions have the following generic advantages and disadvantages:

Advantages

- Ability to significantly reduce flooding in Charleville from Bradley's Gully; and
- Widely accepted by the community as a viable option.

Disadvantages

- Significant cost;
- Increase in Warrego River flood levels;
- Marginal reduction in flow capacity when the Warrego River is also in flood; and
- Significant ongoing maintenance costs.

Further discussion in respect of each of the identified locations is given in the following paragraphs.

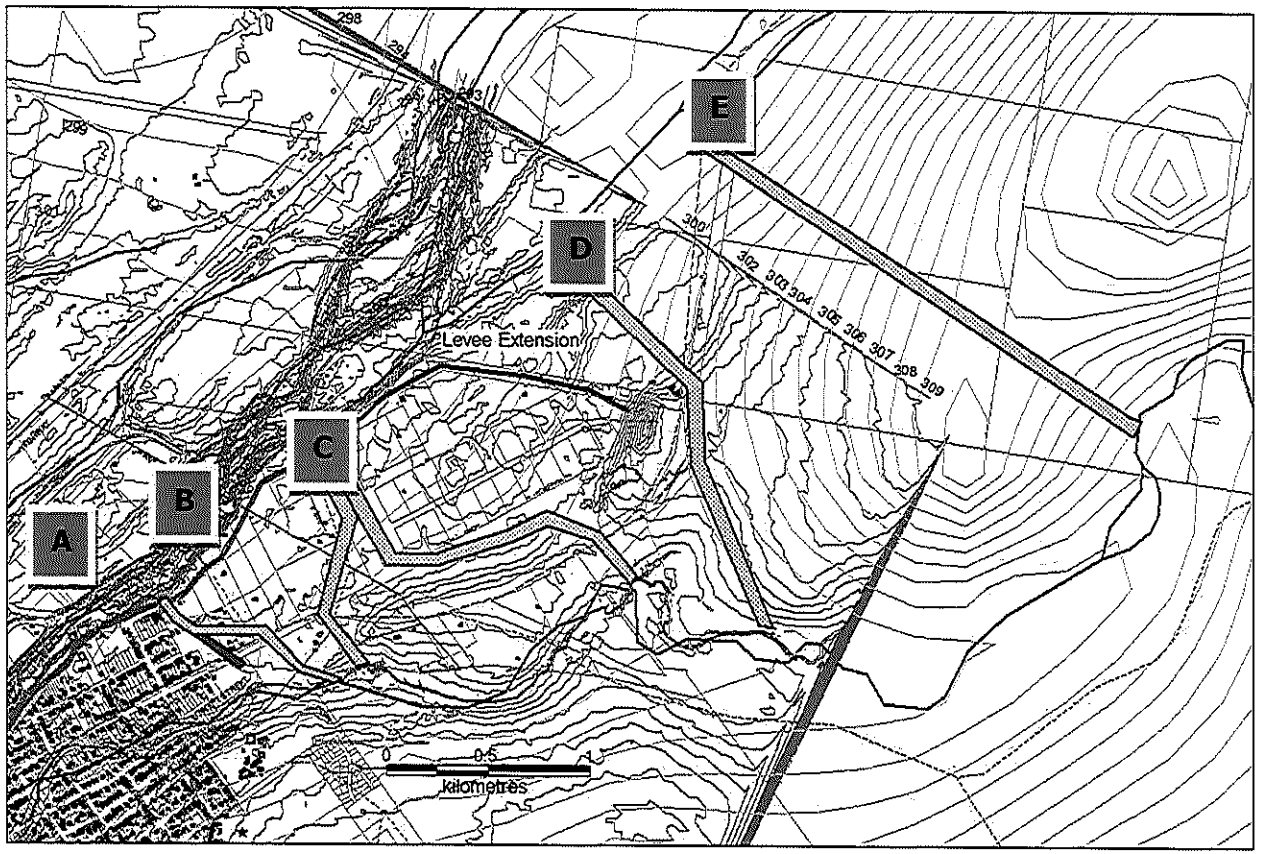

Figure 17 Bradley's Gully Possible Diversion Routes to Warrego River

a) Diversion A

Diversion A is the nearest to the town and is essentially an enhancement of the natural breakout flow path at this location.

This would comprise the following:

- Continuation of the existing levee through the paddocks to the east of Hunter Street on both banks of the breakout flow path;
- Excavation of the breakout flow path to increase its flow capacity;
- Removal of the section of existing levee across the mouth of the breakout flow path;
- Construction of a small diversion dam across Bradley's Gully with a low flow pipe to limit flows through the town to be within the channel capacity;
- Construction of a culvert crossing of the diversion along Alfred Street; and
- Resumption or partial resumption of a number of properties including 2 houses and change of access to a third house;
- Construction of a levee alongside Wellwater Road (or raising part of the road to act as a levee) to prevent the breakout flow which occurs there and floods properties along Banjarra Drive.

This option has the following advantages and disadvantages:

Advantages

- This is the shortest diversion route at about 800m and hence lower costs;

Disadvantages

- Proximity to town could be a disadvantage when overtopped in an extreme flood;
- Requires resumption of a number of properties including 2 houses;
- Width is restricted to about 100m hence requiring bed protection; and
- Bridging of Alfred Street required.

A concept plan for Diversion A is given in **Figure 18** and **Figure 19** shows the modelled 100 year ARI (1% AEP) flood extent with the Warrego River at low level. This shows only minor flooding immediately adjacent to the diversion and through the town.

b) Diversion B

Diversion B would divert flow from Bradleys Gully south of the junction of Alfred Street with Wellwater Road and along the Erbacher Street road reserve discharging into the Warrego River, as shown in **Figure 20**.

This would comprise the following:

- Construction of a small diversion dam across Bradley's Gully with a low flow pipe to limit flows through the town to be within the channel capacity;

- Excavation of the diversion channel with bed width of 100m and 1 in 4 batters, length 1,350m;
- Construction of levees along both banks of the channel;
- Construction of a culvert crossing of the diversion near the Alfred Street/Wellwater Road junction;
- Partial resumption of a number of properties (no houses) with a significant proportion of the construction being on public land; and
- Construction of a levee alongside Wellwater Road (or raising part of the road to act as a levee) to prevent the breakout flow which occurs there and floods properties along Banjarra Drive.

This option has the following advantages and disadvantages:

Advantages

- Diversion length is relatively short;
- Further from the town;

Disadvantages

- Requires partial resumption of a number of properties;
- Width is restricted to about 100m hence requiring bed protection;
- Requires inlet weir to give same level of protection against Warrego flood as existing levee; and
- Bridging of Alfred Street required.

c) Diversion C

Diversion C is located further upstream and crosses Wellwater Road at the low point where Bradley's Gully naturally breaks out, then turns east alongside Wellwater Road and, as for Option B, along Erbacher Street reserve to the Warrego River, as shown in **Figure 22**.
This would comprise the following:

- Construction of a small diversion dam across Bradley's Gully with a low flow pipe to limit flows through the town to be within the channel capacity;
- Excavation of the diversion channel with bed width of 100m and 1 in 4 batters, length 2,100m;
- Construction of levees along both banks of the channel;
- Construction of a culvert crossing of the diversion along Wellwater Road;
- Partial resumption of a only 1 property with most of the construction being on public land; and
- Construction of a levee alongside Wellwater Road (or raising part of the road to act as a levee) to prevent the breakout flow which occurs there and floods properties along Banjarra Drive.

This option has the following advantages and disadvantages:

Advantages

- Makes the most of the Wellwater Road and Erbacher Street road reserves to minimise the need for property resumption;

Disadvantages

- High cost;
- Width is restricted to about 100m hence requiring bed protection; and
- Bridging of Wellwater Road required.

d) Diversion D

Diversion D is the furthest from the town and the only one of the sites where channel width is not constrained and hence can be built wide enough to not need bed protection. A concept layout for Diversion D is given in **Figure 24**.

This would comprise the following:

- Construction of a small diversion dam across Bradley's Gully with a low flow pipe to limit flows through the town to be within the channel capacity;
- Excavation of the diversion channel with bed width of 250m and 1 in 4 batters, length 2,300m;
- Construction of levees along parts of both banks of the channel;
- Construction of a causeway or culvert crossing of the diversion along Wellwater Road; and
- Partial resumption of only 2 properties.

This option has the following advantages and disadvantages:

Advantages

- Can be constructed wide enough so that bed protection against erosion is not required; and
- Remote from the town.

Disadvantages

- Highest cost; and
- Crossing of Wellwater Road required, but this could be by causeway if all-weather access is not required.

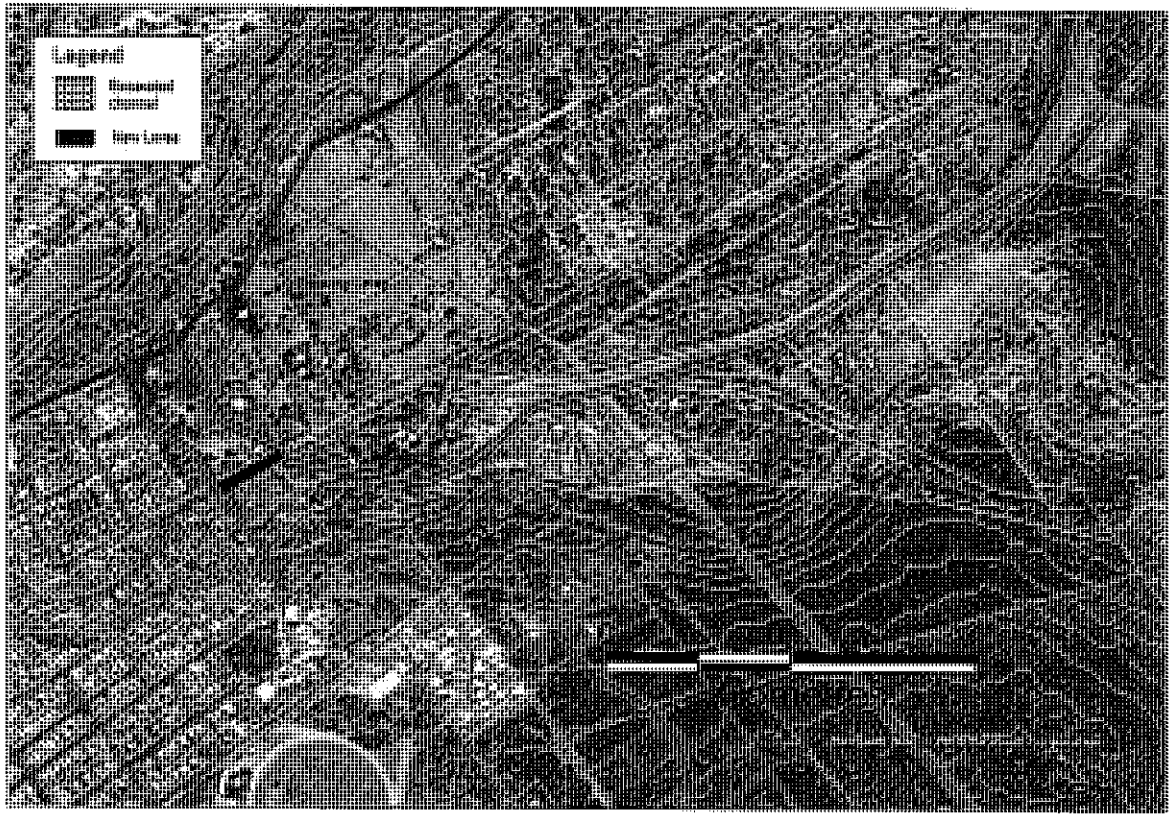

Figure 18 Concept Plan - Diversion A

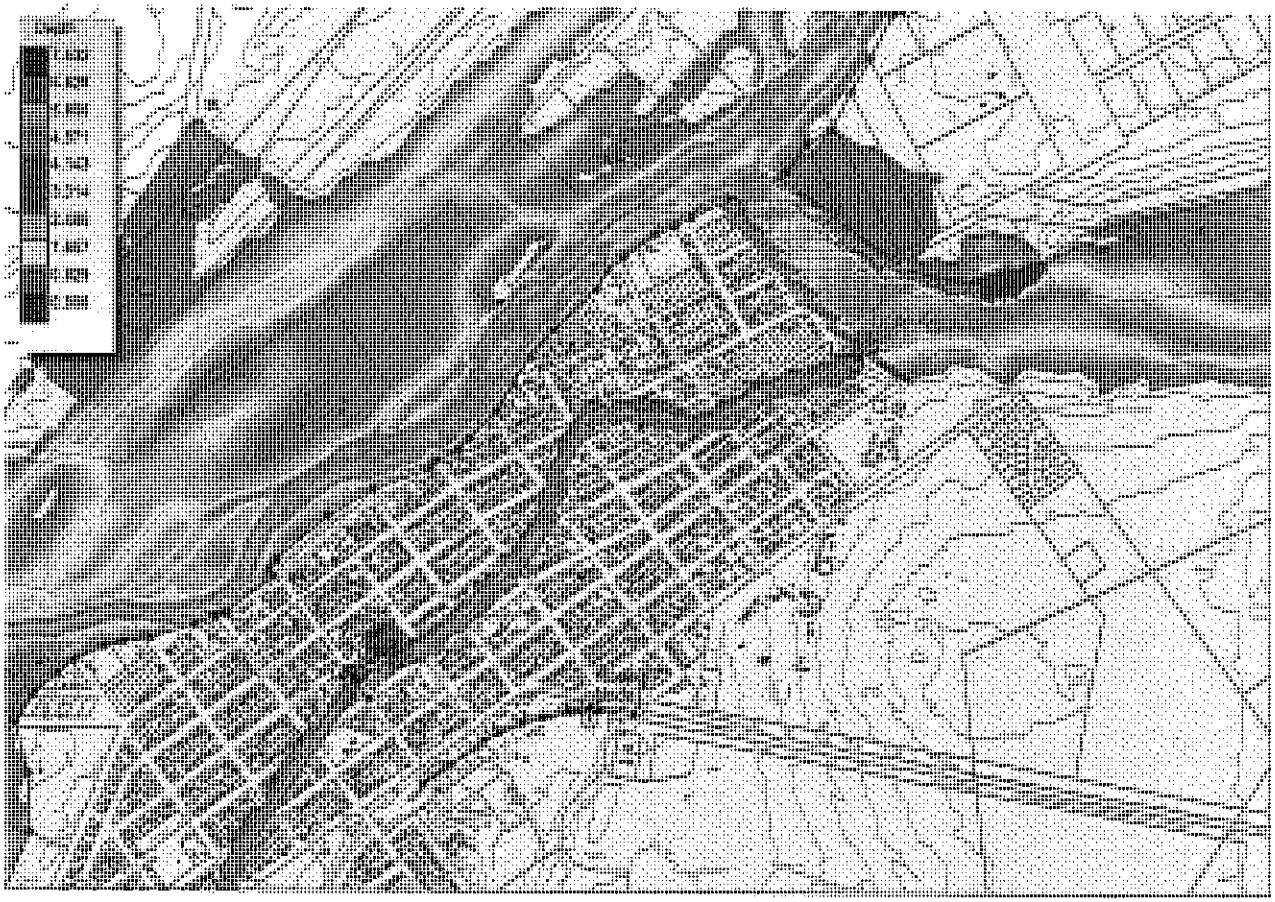

Figure 19 **Modelled Bradley's Gully Peak 100 Year ARI Flood Level with low Warrego River level - Diversion A**

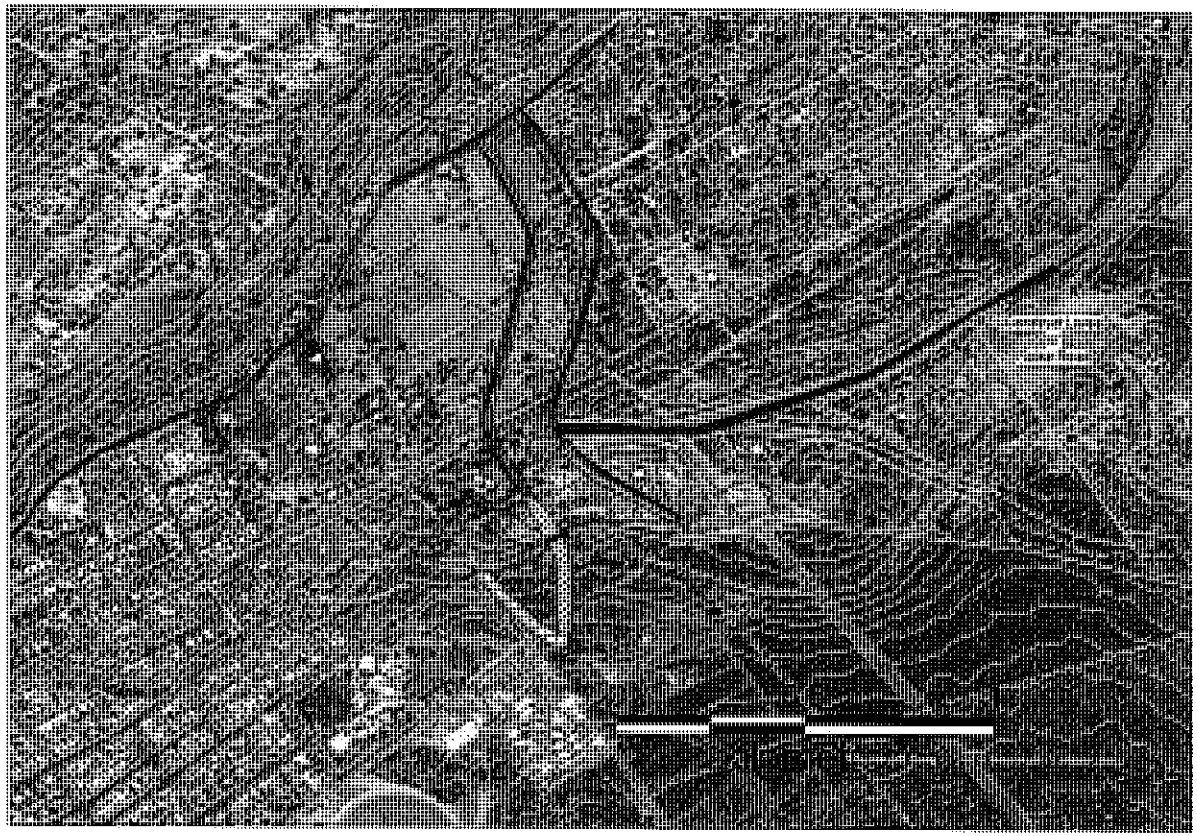

Figure 20 Concept Plan - Diversion B

Figure 21 **Modelled Bradley's Gully Peak 100 Year ARI Flood Level with low Warrego River level - Diversion B**

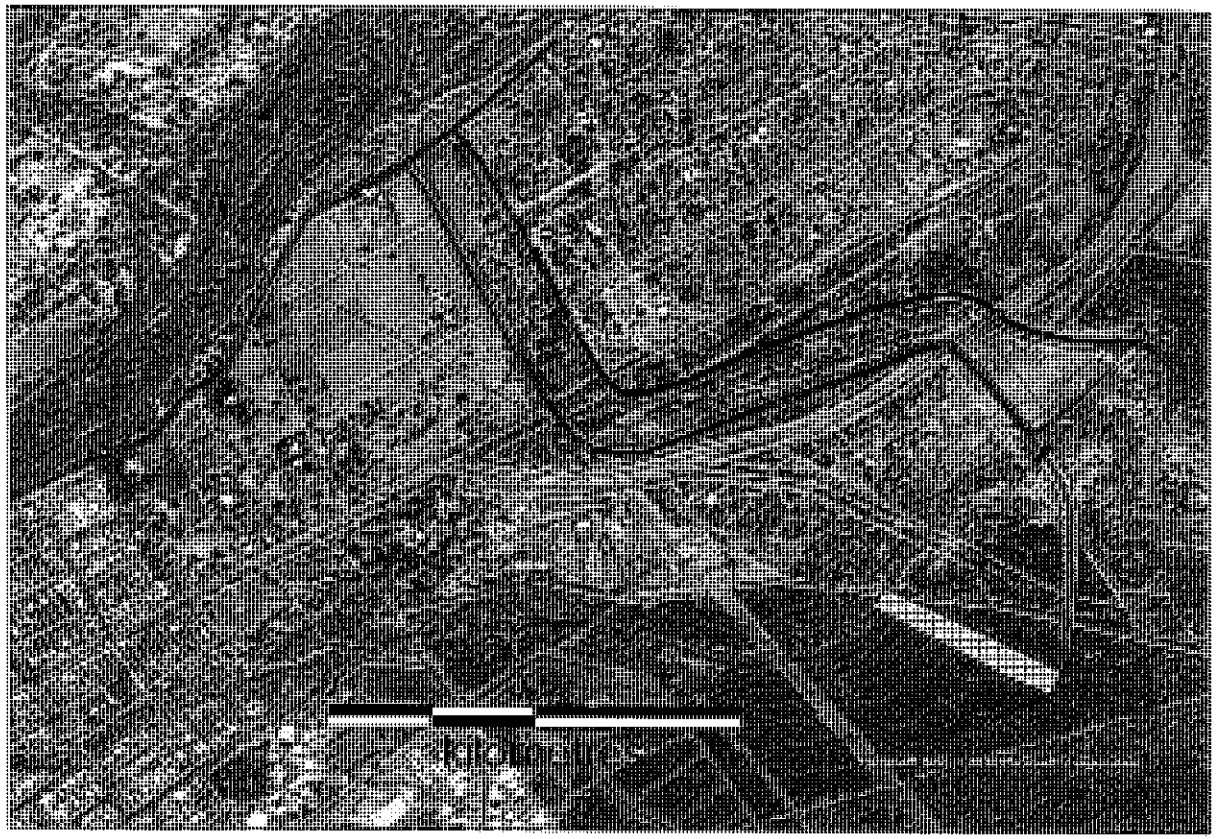

Figure 22 Concept Plan - Diversion C

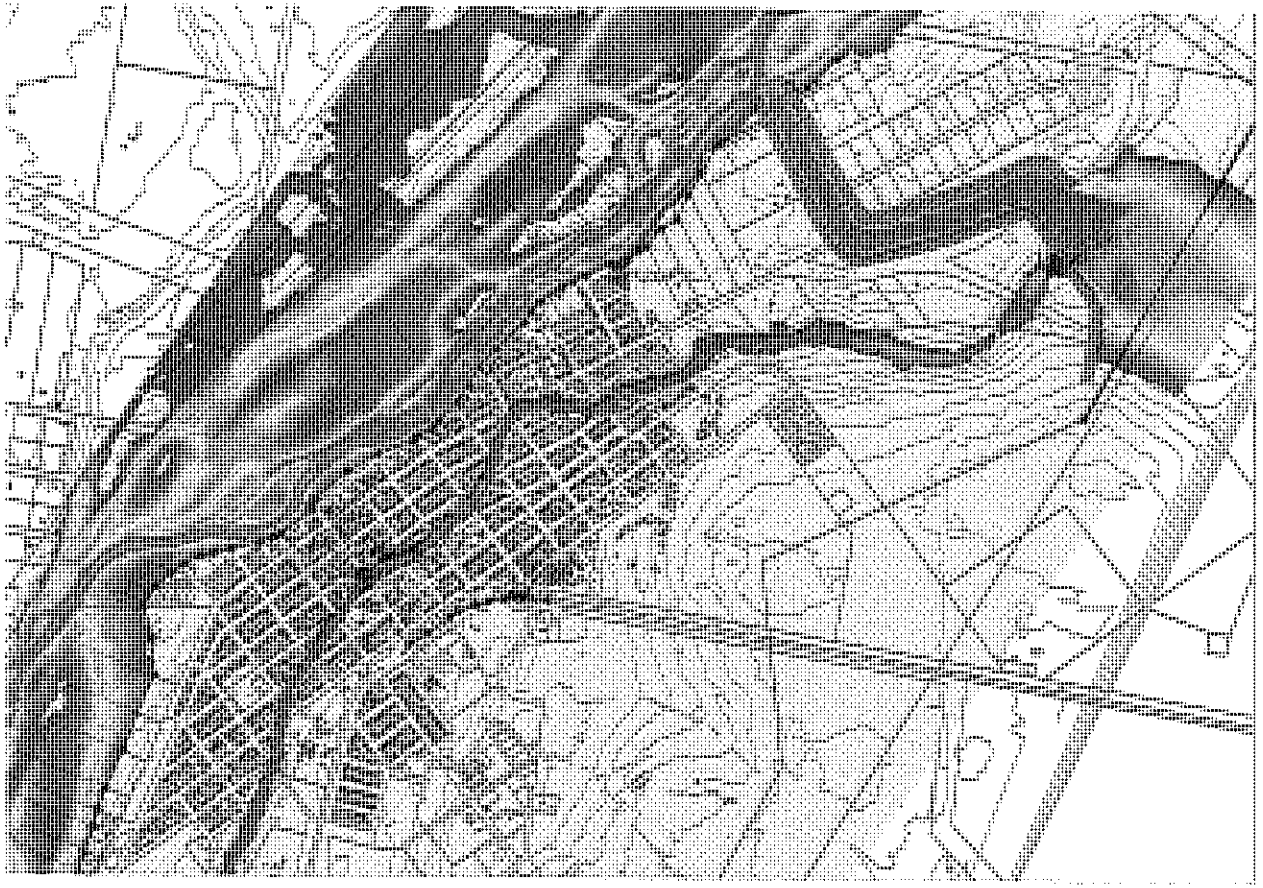

Figure 23 **Modelled Bradley's Gully Peak 100 Year ARI Flood Level with low Warrego River level - Diversion C**

Figure 24 Concept Plan - Diversion D

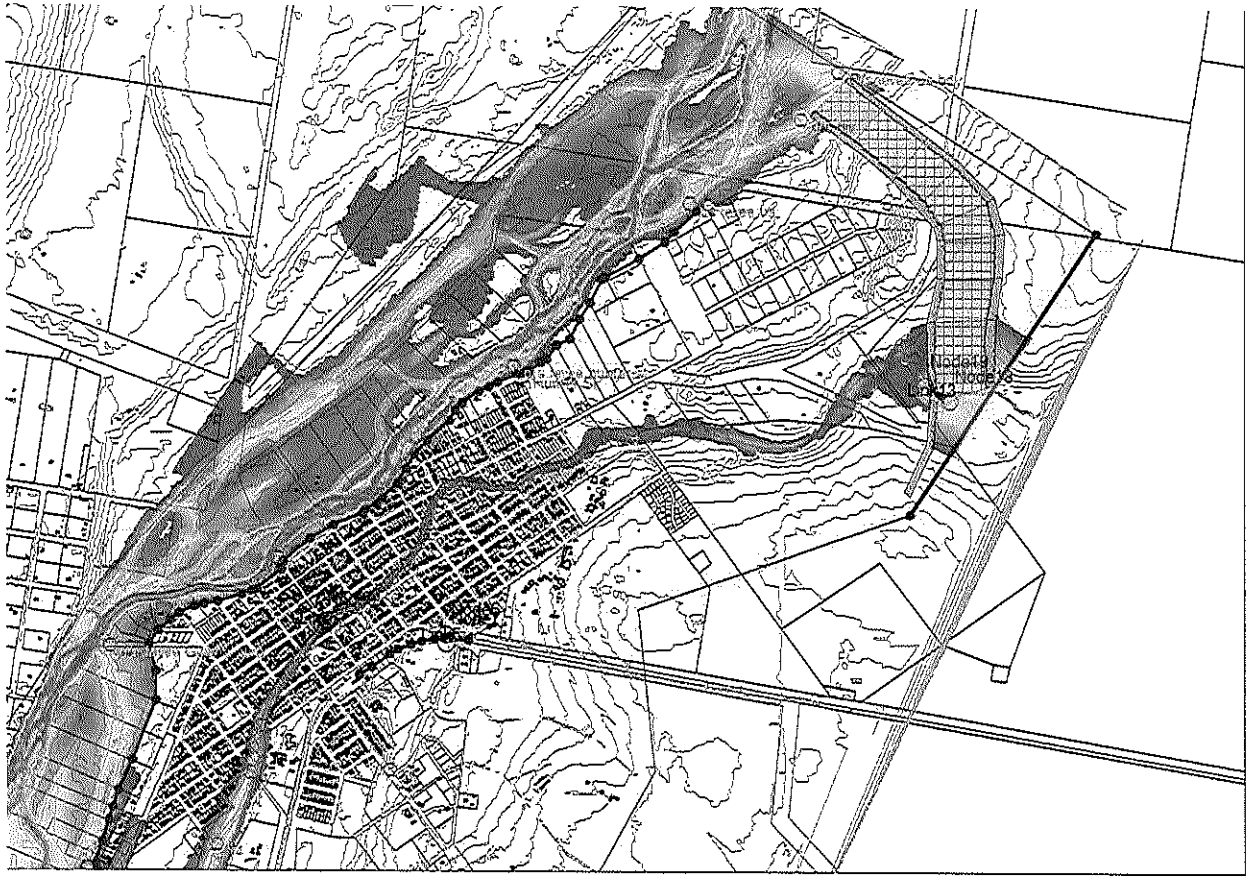

Figure 25 Modelled Bradley's Gully Peak 100 Year ARI Flood Level with low Warrego River level - Diversion D

5.1.2 Diversion of Breakouts within Charleville

In the Interim Report, it was recommended that the breakout from near Burcher Street to Hunter Street be re-opened as soon as possible in order to provide some immediate relief, should another flood occur before the major works are constructed. This was to be done by replacing the section of levee to the east of Hunter Street with a simple gate system, by means of stop logs or some other simple device, which could be removed should Bradley's Gully flood in the absence of a Warrego River flood as occurred this year. Alternatively, this could be achieved by means of significantly increasing the pipe capacity through the levee, to say at least 5 pipes of 1500mm diameter.

However, the 2D hydraulic modelling has shown this to be of limited effect without construction of a levee from the proposed levee breach to and across Bradley's Gully to limit the flow continuing down the gully.

This aspect is dealt with in other sections herein dealing with both diversion option A and the diversion weir associated with the retarding basin option.

The hydraulic modelling has shown that the second breakout will no longer occur once either an upstream diversion or retarding basin are in place and hence this has not been given any further consideration.

5.1.3 Diversion Downstream of Charleville

Bradley's Gully enters the Warrego River about 6km downstream of Charleville. Some of the submissions suggest that some or all of this reach be "cleaned" out to increase its capacity. Such channel deepening/widening is seldom successful and can initiate widespread erosion.

An alternative may be the construction of a diversion channel to return Bradley's Gully flow into the Warrego River further upstream. This would be of some benefit in Bradley's Gully floods in which the Warrego River is not in flood, but is unlikely to be very effective when the Warrego River its itself at a relatively high level.

This requires detailed modelling to evaluate its efficacy, and is recommended for inclusion in the detail study.

5.1.4 Diversion South into Angellala Creek

A number of submissions have suggested diversion of Bradley's Gully floodwaters south in the Angellala Creek catchment. Some preliminary locations have been identified from the 9 second DEM and are given in **Figure 26**.

These potential diversions have the following advantages and disadvantages compared to diversions upstream of Charleville:

Advantages

- No impact on Warrego River flood levels.

Disadvantages

- Greater cost;
- Ability to divert only part of the flow at Charleville which alone would be insufficient to prevent flooding at Charleville;
- Potential problems for downstream landowners; and

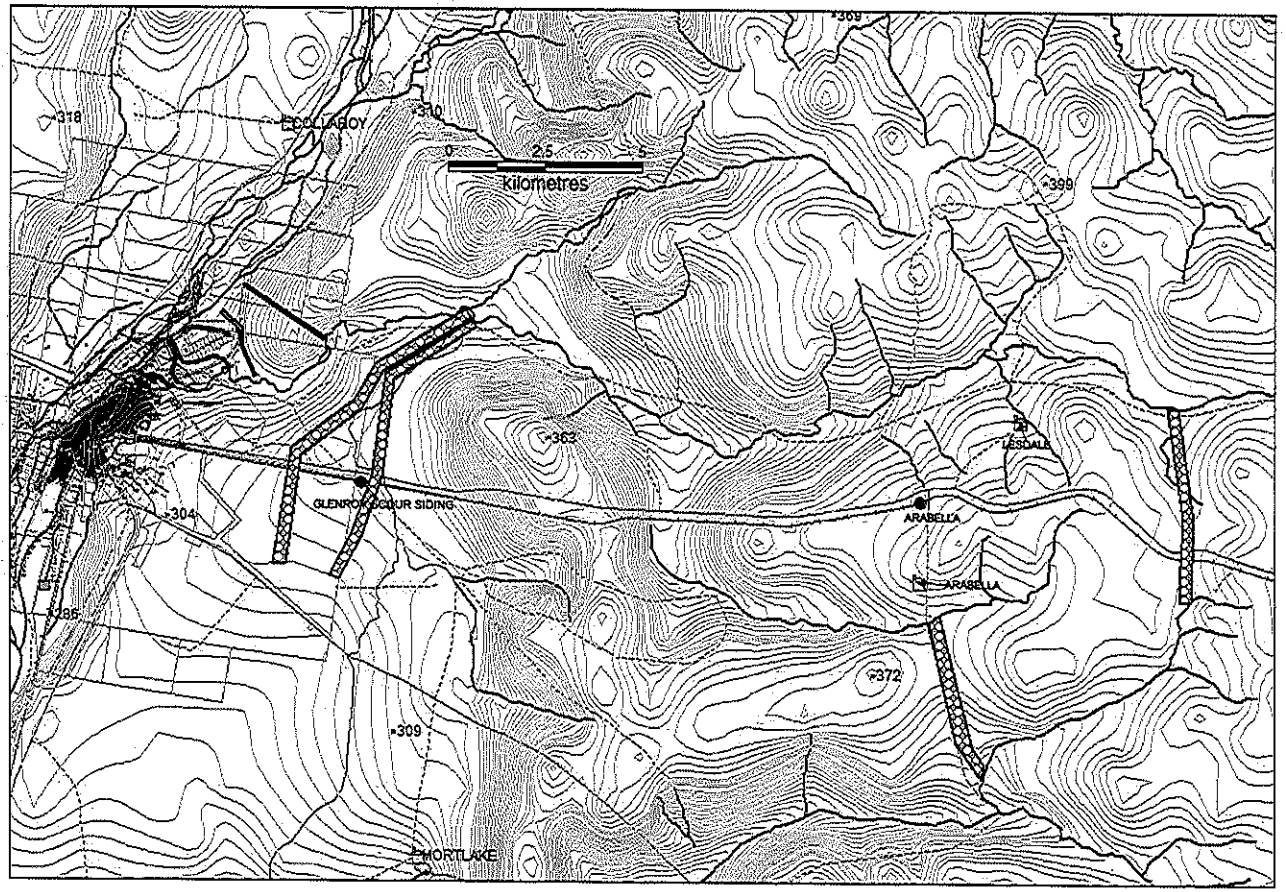

Figure 26 Bradley's Gully - Possible Diversions to Angellala Creek

- Difficulty of obtaining approval from DERM due to transfer of flow from on sub-catchment of the Warrego River to another.

As each of these possible diversions are:

- longer than any of those considered upstream of Charleville and therefore greater cost;
- as a result of being further upstream, only able to divert part of the flow reaching Charleville and would still require a further diversion upstream of Charleville to sufficiently reduce flooding through the town; and
- unlikely to be able to be successfully promoted due to the disadvantages listed above.

It was determined on this basis, that these options do not warrant further investigation at this time.

5.2 Bradleys Gully Flood Storage

A number of potential flood mitigation storage sites have been identified in the Bradleys Gully catchment, and these are shown in **Appendix C.** These sites have been identified from the 9 second DEM.

In order to maximise their flood mitigation potential and to minimise other problems such as maintenance of a permanent water storage, it is recommended that these be considered as retarding basins, that is, these are empty except when during flood, and have permanent low level outlets in the form of large pipes or culverts (with no moving parts) and simple overflow spillways,, hence minimising the maintenance requirements. It is likely that any such storage, to be effective, will be sufficiently large, to be a "referable dams" under the *Water Supply (Safety and Reliability) Act (2008)* and require DERM licensing and subsequent performance monitoring. This will require a failure impact assessment (FIA) as part of the design study.

Geotechnical studies will be required to determine whether and where materials suitable for construction are available, and for the design of stable embankment dams using these materials.

Hydrologic evaluation has been be undertaken for the three of these sites nearest to Charleville, as these have the greatest flood mitigation potential.

These sites are:

- **Site 1** – this site has advantages in being relatively close to the town and so commands most of the Bradley's Gully catchment – it also offers the possibility of spillway discharge direct to Warrego River and hence creating a partial diversion;
- **Site 1a** is a variant on Site 1 but has smaller storage but could also be constructed together with a retarding basin at Site 2; and
- **Site 2** is the site near the junction of Middle Creek and Bradley's Creek inspected on 13th May. This option also offers the possibility of spillway discharge direct to Warrego River and hence creating a partial diversion.

The hydrologic evaluation of these sites is given in **Appendix C**, from which it was concluded that sufficient storage exists at both sites 1 and site 2, but not at site 1a to significantly mitigate flooding from Bradley's Gully downstream of the retarding basin.

A number of outlet sizes and spillway capacities were tested with the outcomes summarised in **Table 7**. Concept design outlines are given in **Figure 27** and **Figure 28**.

Figure 29 shows the residual flooding in Charleville in a 1% AEP (100 year ARI) event with Retarding Basin 1 in place, from which it can be seen that whilst the flooding is significantly reduced, there are still some areas flooded. This is due to local inflow downstream of the retarding basin which cannot be controlled in this way.

In order to further reduce the flooding in the town, a reduced version of Diversion Option A is required in which the levee is extended from east of Hunter Street, to Bradleys Gully and forms a weir across the Gully with a 1500mm diameter pipe though the weir to allow the passage of low flows. The effect of this is to shown in **Figure 30** and an outline of the required works is shown in **Figure 31**.

Table 7 Potential Bradley's Gully Retarding Basin Details

Item	Retarding Basin at Site 1	Retarding Basin at Site 2
Spillway Level	313.0m AHD	316.0m AHD
Dam Crest Level	316.0m AHD	319.0m AHD
Maximum Dam Height	10m	12m
Storage at spillway level	26,000ML	42,000ML
Storage at dam crest level	64,000ML	81,000ML
Low flow outlet	1 no 1800mm diameter	1 no 1800mm diameter
100 year ARI Peak Inflow (Storm Duration)	1050 m^3/s (30 hour)	1050 m^3/s (30 hour)
Peak 100 year ARI Water Level	313.92m AHD	316.6m AHD
100 year ARI Peak Pipe Outflow	$17m^{3/s}$	19 m^3/s
100 year ARI Spillway Flow	43	0
100 year ARI Peak flow in Bradley's Gully at Charleville	41	132

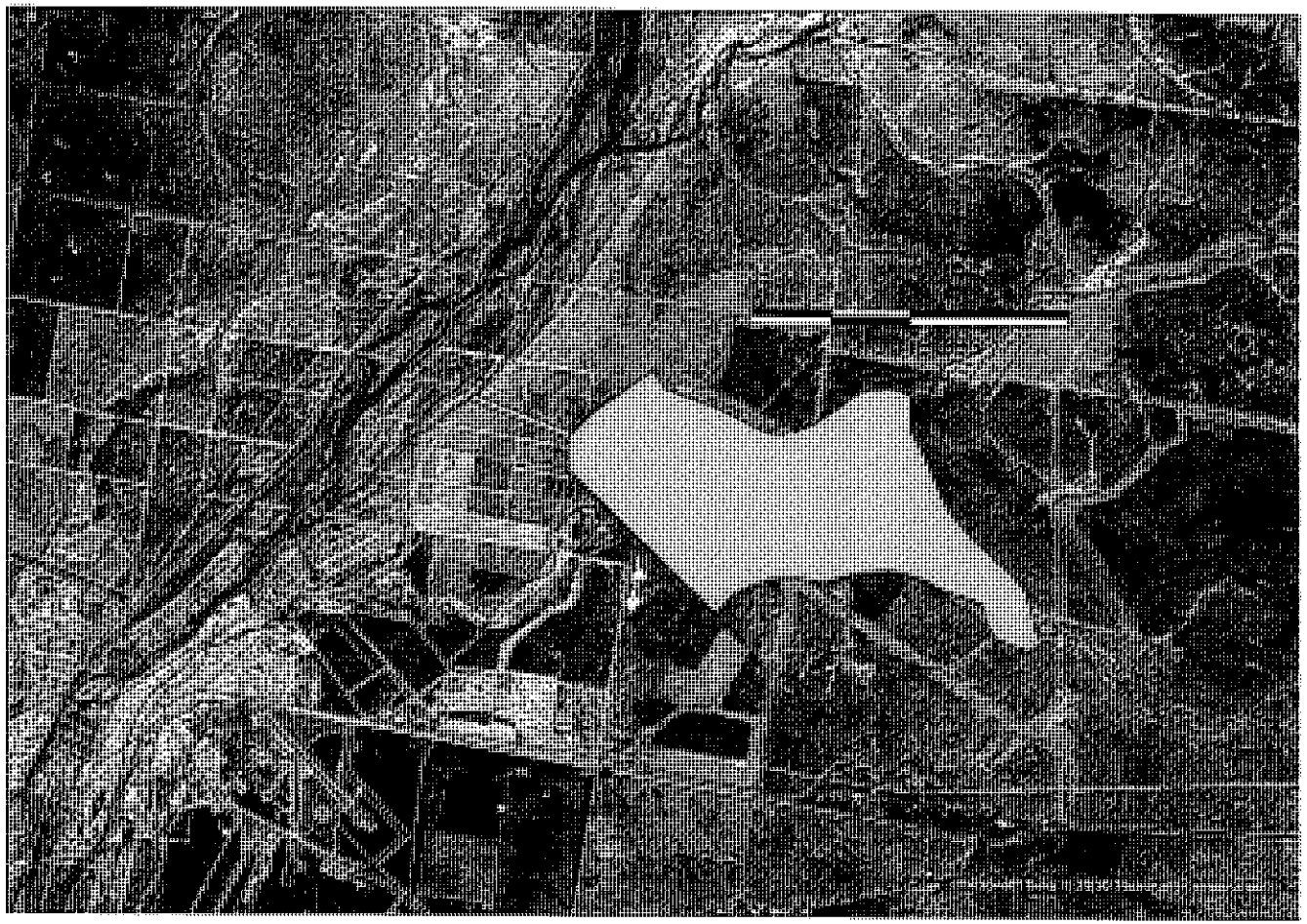

Figure 27 Concept Design - Retarding Basin at Site 1

Figure 28 Concept Design - Retarding Basin at Site 2

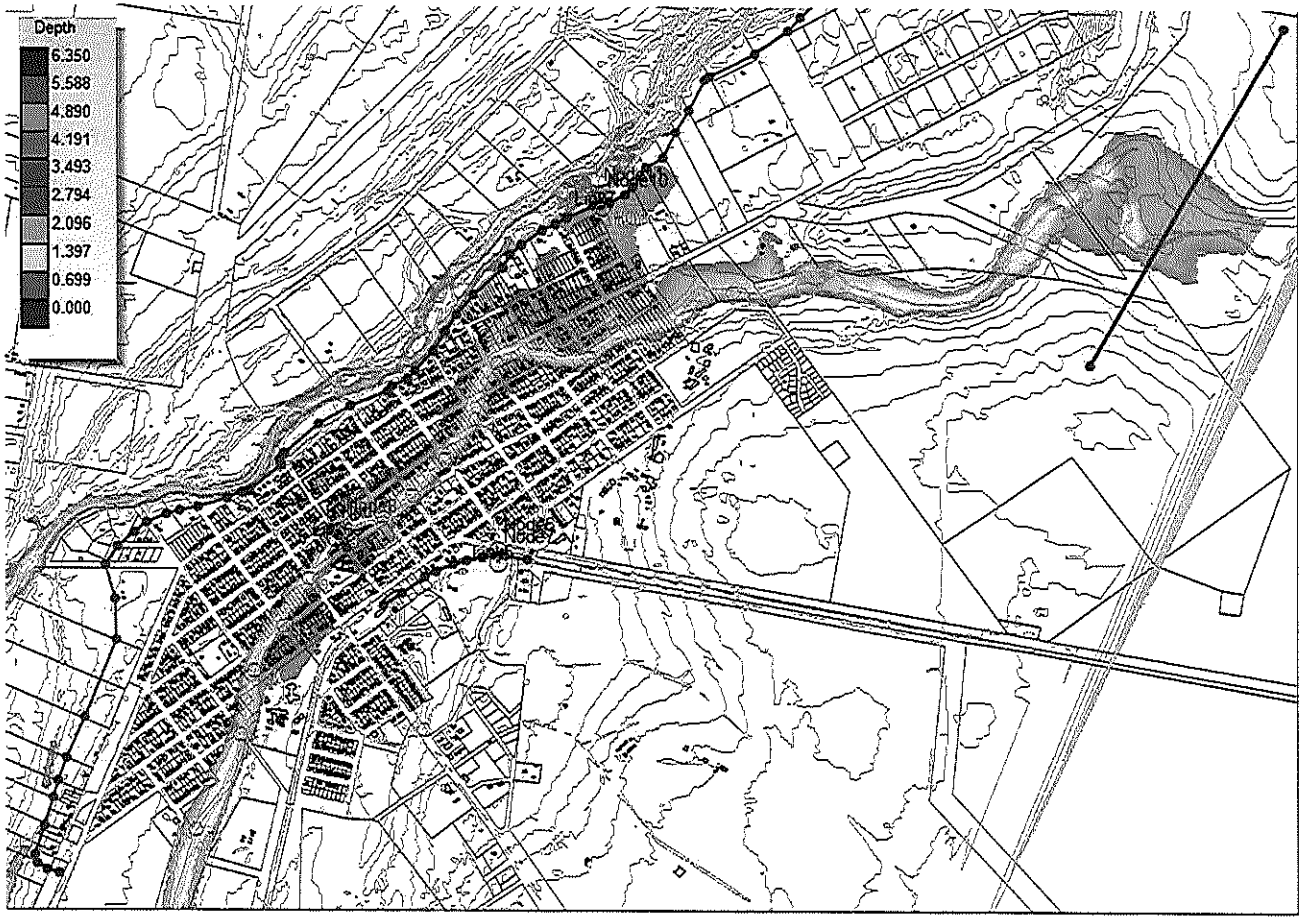

Figure 29 Residual Flooding in Charleville in 100 Year ARI Event with Retarding Basin alone

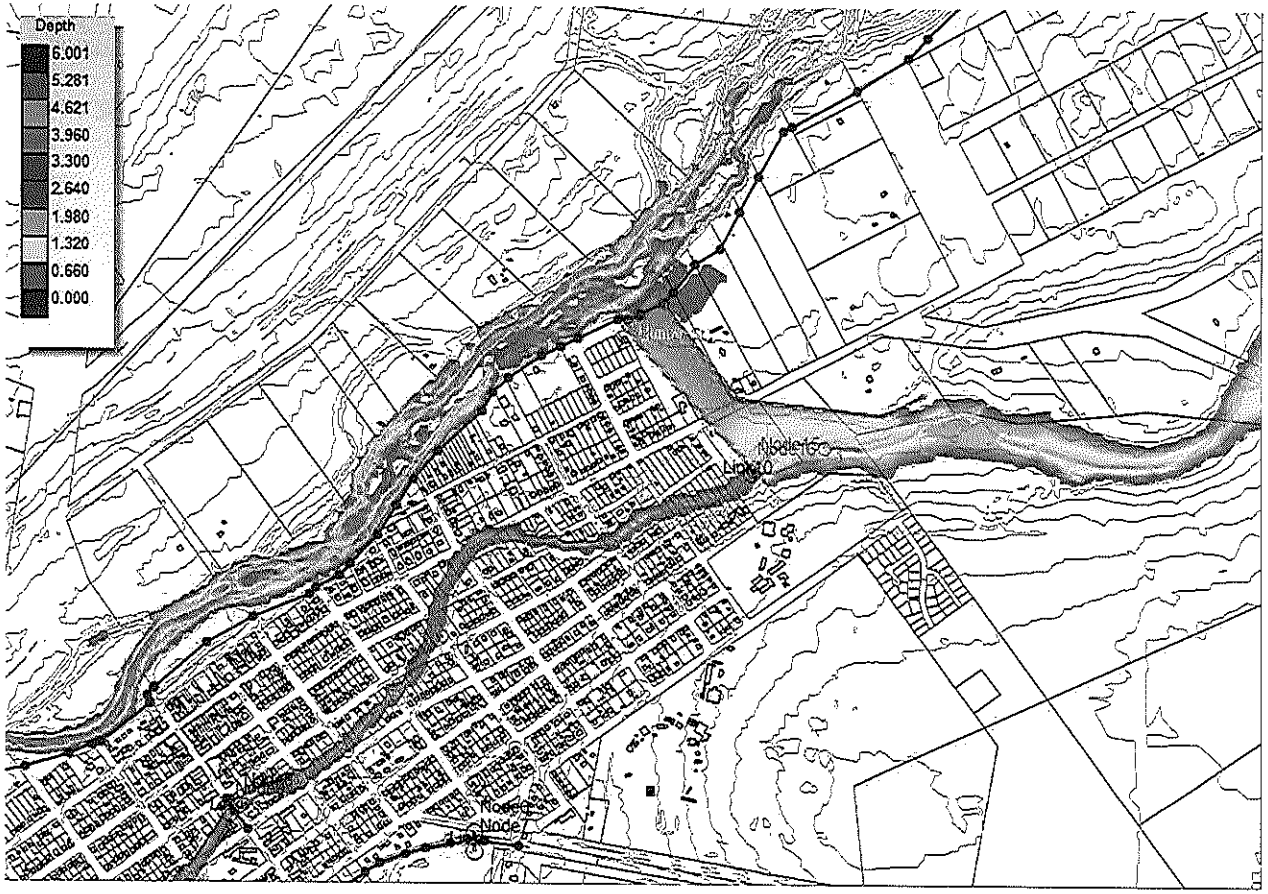

Figure 30 Residual Flooding in Charleville with Retarding Basin and Diversion Weir