GUNNEDAH SHIRE COUNCIL

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT
STUDY AND PLAN

DRAFT STUDY REPORT

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FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the following four sequential stages:

1.	Flood Study	Determines the nature and extent of flooding.
2.	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
3.	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4.	Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

This *Floodplain Risk Management Study and draft Plan* has been prepared for Gunnedah Shire Council with the support of the Department of Environment, Climate Change and Water and follows the *Blackjack Creek Flood Study, 2005* which defined the pattern of flooding in the study area. The study was undertaken under the direction of the Gunnedah Floodplain Management Committee, comprising community, DECCW, Gunnedah Council and Government Agency representatives.

SUMMARY

S1 Study Objectives

Gunnedah Shire Council commissioned the preparation of the *Floodplain Risk Management Study and Plan* for Blackjack Creek. The objectives of the *Floodplain Risk Management Study (FRMS)* were to assess the impacts of flooding, review existing Council policies as they relate to development of land in flood liable areas bordering Blackjack Creek, consider options for management of flood affected land and to develop a *draft Floodplain Risk Management Plan (FRMP)* which:

i) Proposes modifications to existing Council policies to ensure that the development of flood affected land is undertaken so as to be compatible with the flood hazard and risk.

ii) Proposes Flood Planning Levels for the various land uses in the Floodplain.

iii) Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding.

iv) Provides a program for implementation of the proposed works and measures.

The *FRMS* focusses on main stream flooding from Blackjack Creek. The solutions of problems resulting from surcharges of the piped stormwater drainage system, which may occur during localised storms on the residential sub-catchments on the eastern floodplain, are outside the scope of the present investigation.

S2 Study Activities

The activities undertaken in this *Floodplain Risk Management Study* (*FRMS)* included:

- Review of flooding patterns on Blackjack Creek for flood events up to the Probable Maximum Flood (**Chapter 2**).
- Undertaking a consultation program over the course of the study to ensure that the Blackjack Creek community was informed of the objectives, progress and outcomes of the study (**Appendix C**).
- Assessment of the economic impacts of flooding, including the numbers of affected properties and estimation of damages (**Chapter 2** and **Appendix B**).
- Review of current flood related planning controls for Gunnedah and their compatibility with flooding conditions on Blackjack Creek catchment (**Chapter 2**).
- Review of potential floodplain management measures aimed at reducing flood damages, including an economic assessment of each measure (**Chapter 3** and **Appendix A**).
- Ranking of measures using a multi - objective scoring system which took into account community acceptance, technical, economic, financial, environmental and planning considerations (**Chapter 4**).
- Preparation of a *draft FRMP* for Blackjack Creek (**Chapter 5**).

S3 Summary of Flood Impacts

The study area comprises the urbanised portion of the Blackjack Creek floodplain extending on the eastern floodplain from Lincoln Street to the Oxley Highway, a distance of 2 km along the main arm of the creek.

The catchment area of Blackjack Creek at the Oxley Highway is 24 km^2. Flooding on the stream is "flash flooding" in nature, with flood levels peaking three to four hours after the commencement of heavy rainfall. **Figure 2.1** shows indicative extents of inundation and **Figure 2.2** shows the typical rate of rise of floodwaters at the Oxley Highway.

Floods up to the 5 year ARI are contained within the immediate vicinity of the channel. Damaging flooding would commence in existing residential development to the east of Wandobah Road in the event of a 20 year ARI flood and progressively increase as shown in **Table S.1**. Above-floor flooding would occur in 104 residences at the 100 year ARI level of flooding, when predicted flood damages would be about $3.45 Million (**Table 2.3**) and depths of inundation up to 0.9 m would be experienced.

TABLE S.1
NUMBER OF PROPERTIES FLOODED
BLACKJACK CREEK STUDY AREA

Flood Event Years ARI	No. of Properties Flooded Above Floor Level		
	Residential	Commercial/ Industrial	Public Buildings
20	29	0	0
50	66	0	0
100	104	0	0
PMF	192	1	0

Note: These properties would experience flooding above floor level. Flood liable properties (100 year ARI) are shown on **Figure B8.3** of **Appendix B**.

S4 Flood Hazards

The floodplain has been divided into three hazard zones for the 100 year ARI flood, as shown on **Figure 2.3**. Hazard is related to the depths and velocities of flow, as well as other factors such as the rate of rise of floodwaters and ease of evacuation from the floodplain in the event of a flood emergency. On the basis of those factors, the creek and its eastern overbank extending to Wandobah Road is a zone of high hazard. There is an area of intermediate hazard in the residential area east of Wandobah Road where depths of inundation up 800 mm may be experienced, but with little velocity of flow. In the low hazard zone the velocity of flow would not be significant and the depth of inundation would generally be limited to 300 mm. The significance of these hazard zones to the proposed flood related controls over future development is described in **Section 3.6** of the report.

S5 The Floodplain Risk Management Plan

The *draft Floodplain Risk Management Plan* showing recommended flood management measures for Blackjack Creek is presented in **Table S.2**. The *draft FRMP* includes three non-structural management measures which could be implemented by Council with the assistance of SES, using existing data and without requiring Government funding. These measures have been given a **Priority 1** assessment and are considered to be an essential part of the *FRMP*. The measures are as follows:

- **Measure 1** - The application of a graded set of planning controls for future residential development that recognises the location of the development in the floodplain; to be applied

through Council's existing Flood Policy DCP for Gunnedah, with specific amendments for Blackjack Creek, as proposed in **Section 2.8.6**. Application of these controls by Council in the period pending completion of either of the structural flood mitigation measures (either the riparian corridor/channel improvement scheme or the levee scheme – see below) will ensure that future development in the catchment is compatible with the flood risk. Either of the structural flood mitigation measures would provide protection from main stream flooding up to the 100 year ARI event. As a result, application of the Flood Policy would not be required following construction and existing residences would not then be subject to flood affectation notices.

- **Measures 2** and **3** - Improvements in the SES's emergency management planning for the catchment, including incorporation of the flood related information contained in this study into the Local Flood Plan for Gunnedah and preparation of a "FloodSafe Brochure" identifying the nature and extent of flooding, time of rise of floodwaters and evacuation routes for residents.

All of the other measures require Council and Government funding. Their priorities depend on the results of feasibility studies which are also part of the draft *FRMP.* They have been given a provisional priority ranking which would be confirmed by the results of the respective feasibility study. The measures are as follows:

- **Measure 4** - Further development of the design concept for the riparian corridor/channel improvement scheme along Blackjack Creek in the 1.9 km reach, commencing at a point about 400 m downstream of Lincoln Street and continuing to the Oxley Highway. This investigation would involve refining the concept design and cost estimates developed in **Chapter 3** of this report and would also include further survey and engineering analysis. This investigation is required to confirm the engineering feasibility and economic merit of the scheme and provide documentation to a standard necessary to support an application for Government funding for the project.
- **Measure 5** - Depending on the results of the above investigation and agreement on the provision of funding, preparation of detailed design and documentation of the riparian corridor/channel improvement scheme, followed by its construction as funding becomes available.
- **Measures 6** and **7** - In the event that the above investigations for the riparian corridor/channel improvement do not confirm its economic feasibility, a flood protection levee running over a similar extent could be considered as an alternative flood mitigation measure. However, further survey and technical investigation of this scheme would be required than is possible in this study, which is strategic in nature. The investigation would involve additional survey and hydrologic analysis to assess requirements for the capture and disposal of runoff derived from the local stormwater catchments on the eastern side of Blackjack Creek. These investigations would be required to confirm the engineering feasibility and economic merit of the levee and provide documentation to a standard necessary to support an application for Government funding for the project.
- **Measures 8** and **9** - Further Investigation of the feasibility of a Flash Flood Warning System for the catchment and development of the scheme if justified. This scheme could be adopted to provide advance warning of flooding on the Blackjack Creek catchment in the event that the two structural measures (channel improvement/riparian corridor, or flood protection levee) do not proceed in a reasonable timeframe. The scheme would not affect the pattern of flooding in the study area but would allow residents to reduce damages to contents and safely evacuate prior to the arrival of floodwaters.

S6 Timing and Funding

The total estimated cost to implement the preferred floodplain management strategy comprising **Measures 1** to **5** (the non-structural measures plus the feasibility study of the riparian corridor/channel improvement scheme, followed by its detailed design and construction) is $2.52 Million, exclusive of Council and SES Staff Costs for the non-structural measures. The timing of the riparian corridor/channel improvement scheme will depend on Council's overall budgetary commitments and the availability of Council and Government funds.

TABLE S.2
RECOMMENDED MEASURES FOR INCLUSION IN BLACKJACK CREEK DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

Measure	Required Funding	Features of the Measure	Priority
1. Implement controls over future residential development based on Council's existing *Flood Policy,* as amended to incorporate flood data for Blackjack Creek.	Council's staff costs	▪ Control residential development in floodplain as summarised in *Flood Policy* (ref. **Section 3.6**). ▪ Graded set of flood controls based on location within the Flood Planning Area, defined as land inundated by the 100 year ARI flood plus 500 mm freeboard. ▪ Floodplain divided into four zones of decreasing flood hazard: **Floodway**, **Intermediate Floodplain**, **Flood Fringe** and **Outer Floodplain**. ▪ Flood Vulnerable development (e.g. housing for aged persons and persons with disabilities) are to be excluded from the floodplain (land inundated by the PMF). ▪ Council's evaluation of development proposals to use data presented in Blackjack Creek Flood Study, 2005 and in this *FRMS, 2010.* ▪ This would be an interim measure pending construction of the riparian corridor/channel improvement scheme, which would provide a 100 year ARI level of protection to residents bordering the creek.	**Priority 1**: this measure has a high priority for inclusion in the *FRMP*. It does not require Government funding.
2. Ensure flood data in *this Floodplain Risk Management Study and Plan* are available to SES for inclusion in flood response procedures.	SES costs	▪ SES's *Gunnedah Local Flood Plan, 2002* should be updated using information on locations of flood prone development incorporated in the *FRMS* and shown in **Figure B8.3** of **Appendix B**.	**Priority 1**: this measure would improve emergency management procedures and has a high priority. It does not require Government funding.
3. Implement flood awareness and education program for residents bordering the creek.	SES, Council staff costs	▪ Council and SES should prepare a *FloodSafe Brochure* to inform residents of the flood risk, based on the information presented in the *FRMS*.	**Priority 1**: this measure would reduce flood losses and has a high priority. It does not require Government funding.
4. Feasibility Study of riparian corridor/channel improvement scheme for Blackjack Creek in the Wandobah Reserve area.	$80,000	▪ Survey along channel route. ▪ Prepare concept design; refine initial costing and economic analysis presented in this *FRMS*. ▪ Undertake Community Consultation. ▪ Prepare a submission for Council and Government funding.	**Priority 1**: this measure is the first step in providing the scheme and has a high priority in view of the flood risk, as well as economic and social impacts resulting from flooding. It requires Council and Government funding.
5. Preparation of detailed design and construction of the riparian corridor/channel improvement scheme	$2.44 Million	▪ Prepare detailed design and documentation of scheme. ▪ Scheme is to be implemented by Council when funding available. ▪ Costs comprise capital and annual maintenance costs.	**Priority 1**: this measure would depend on a favourable outcome from the above Feasibility Study and on the availability of Council and Government funding.
6. Feasibility Study of a flood protection levee along the eastern bank of Blackjack Creek in the Wandobah Reserve area.	$80,000	▪ Survey along levee route. ▪ Prepare concept design; refine initial costing and economic analysis presented in this *FRMS*. ▪ Undertake Community Consultation. ▪ Prepare a submission for Council and Government funding.	**Priority 2**: this measure is an alternative to the riparian corridor/channel improvement scheme. It requires Council and Government funding.
7. Preparation of detailed design and construction of the levee scheme (dependent on the results of the above study)	$2.67 Million	▪ Prepare detailed design and documentation of scheme. ▪ Works are to be implemented by Council when funding available. ▪ Costs comprise capital and annual maintenance costs.	**Priority 2**: this measure would depend on a favourable outcome from the Feasibility Study and the availability of Council and Government funding.
8. Undertake investigation of feasibility of a Flash Flood Warning System.	$50,000	▪ The system would be based on the "Total Warning System" outlined in **Section 3.9**. ▪ Floor levels of residential development bordering the creek which were surveyed for this present study and results of the Blackjack Creek Flood Study, 2005 would be used as basic data for the system. ▪ Further investigation is required to relate predicted rainfalls to the incidence and locations of flooding problems in the study area. ▪ The above investigation could be expanded to incorporate problems due to surcharging of the local stormwater system.	**Priority 3**: this measure would alert residents to take action to reduce flood losses in the urban area on the eastern side of Wandobah Road. Its priority depends on whether or not either of the structural mitigation schemes (channel improvement/riparian corridor or levee) is implemented.
9. Implementation of Flash Flood Warning System	$360,000	▪ Cost allows for instrumentation, software, training and public flood awareness program. ▪ Allow an additional annual cost of $15,000 for maintenance of the system (Council costs). ▪ Costs comprise capital and annual maintenance costs.	**Priority 3**: implementation of this measure would depend on a favourable outcome from the above Feasibility Study and the availability of Council and Government funding.
Total Estimated Cost (Preferred Strategy)	**$2.52 Million**	**Note: Preferred strategy comprises Measures 1 to 5.**	

1 INTRODUCTION

1.1 Study Background

Blackjack Creek runs along the western side of Gunnedah through the area known as the Wandobah Reserve. The stream crosses the Oxley Highway and the railway, before discharging to the floodplain of the Namoi River about 1.7 km downstream of the railway. Land use on the eastern floodplain between Lincoln Street and the highway is residential in nature. The creek and the western floodplain are grassed with isolated stands of trees. The creek channel is indistinct and of limited hydraulic capacity.

Flooding on Blackjack Creek has resulted in damage to residential properties on the eastern floodplain. Major storms in January 1984 and November 2008 are reported to have caused surcharging of the creek, resulting in flooding extending into the residential area. Flood waters extended into allotments and above-floor inundation occurred in several residences. Flooding in the catchment was of a "flash flooding" nature, with peak flood levels occurring about 2 to 3 hours after the commencement of heavy rainfall. During periods of heavy rainfall the local piped stormwater system surcharges with overland flows being conveyed along several of the streets. High water levels in Blackjack Creek coincident with storms on the local catchment could inhibit the escape of overland flows to the creek in the Wandobah Road area.

Gunnedah Shire Council commissioned the Blackjack Creek Flood Study (LACE, 2005), which assessed main stream flooding patterns. The Blackjack Creek Flood Study was the first part of the NSW Government's Floodplain Risk Management process, which aims to reduce the impact of flooding and flood liability for flood prone land in the catchment and represented a detailed technical investigation of flood behaviour. Subsequently, Council commissioned the preparation of the *Floodplain Risk Management Study (FRMS)* and *draft Plan (FRMP)* for the catchment (this present investigation). The *FRMS* and *FRMP* represent the next phase of the Government's management process.

Figure 1.1 shows the study area, the focus of which is the residential area on the eastern floodplain between Lincoln Street and the Oxley Highway. The first steps in the *FRMS* were the collection of flood data via a Community Newsletter/Questionnaire which was distributed by Council to residents bordering Blackjack Creek and the review of the 2005 Flood Study. Based on the knowledge of flooding patterns and a survey of the floor levels of properties located within the floodplain, the economic impacts of flooding were assessed. Measures aimed at managing the flood risk for existing development and reducing the risk for future development, were then formulated and their feasibility assessed.

The potential flood management measures were ranked by the Committee according to a scoring system based on economic, social and environmental criteria. Based on these results a draft *FRMP* was then prepared under the guidance of the Floodplain Risk Management Committee, made up of local and Government Agency representatives.

1.2 Background Information

In the preparation of the *FRMS* and draft *FRMP*, the Consultants drew on the experience gained from several investigations on flooding in the study catchment and Gunnedah area, as well as planning documentation which included:

- "Blackjack Creek Flood Study", 2005, prepared by Lyall and Associates Consulting Water Engineers.
- "Gunnedah Local Flood Plan", 2002, prepared by State Emergency Service.
- "Gunnedah and Carroll Floodplain Management Study and Plan", 1999 prepared by Snowy Mountains Engineering Corporation.
- Council's DCP "Principles of Development" containing guidelines for development in areas subject to flooding from the Namoi River.
- "Use of Geophysical Methods to Delineate Salt Affected Areas for Channel Reconstruction in Wandobah Reserve Gunnedah, NSW", 2003 prepared by Department of Planning and Natural Resources (now DECCW) and delineating salt affected areas along floodplain of Blackjack Creek
- "Carroll to Boggabri Floodplain Management Plan", 2006, prepared for Department of Planning and Natural Resources.

1.3 Overview of Report

This report sets out the findings of the *Floodplain Risk Management Study* and presents the *draft Floodplain Risk Management Plan*.

Chapter 2 of the Report contains information on baseline flooding conditions on the floodplain, including a review of Council's existing planning policies as they relate to flood affected land, assessment of the impacts of flooding on the community, a review of flood warning arrangements and review of environmental considerations which could influence the works and measures recommended for inclusion in the draft *FRMP*.

Chapter 3 is a review of possible Floodplain Management Measures which could be included in the *FRMP*. Community views obtained from the Community Newsletter/Questionnaire issued to residents at the commencement of the study are summarised, leading to a list of potential flood management measures which are then tested for their feasibility.

Chapter 4 details the selection of Floodplain Management Measures. Floodplain Management strategies comprising combinations of measures are assessed according to a multi-objective scoring system and a preferred strategy is outlined.

Chapter 5 presents the draft *Floodplain Risk Management Plan.*

Chapter 6 contains a list of References.

The Study is supported by **Appendices** which provide additional details of the investigations undertaken for the preparation of the Study and Plan.

- **Appendix A** contains indicative costings for the two structural flood mitigation schemes.
- **Appendix B** is an assessment of the economic impacts of flooding on the Blackjack Creek floodplain.

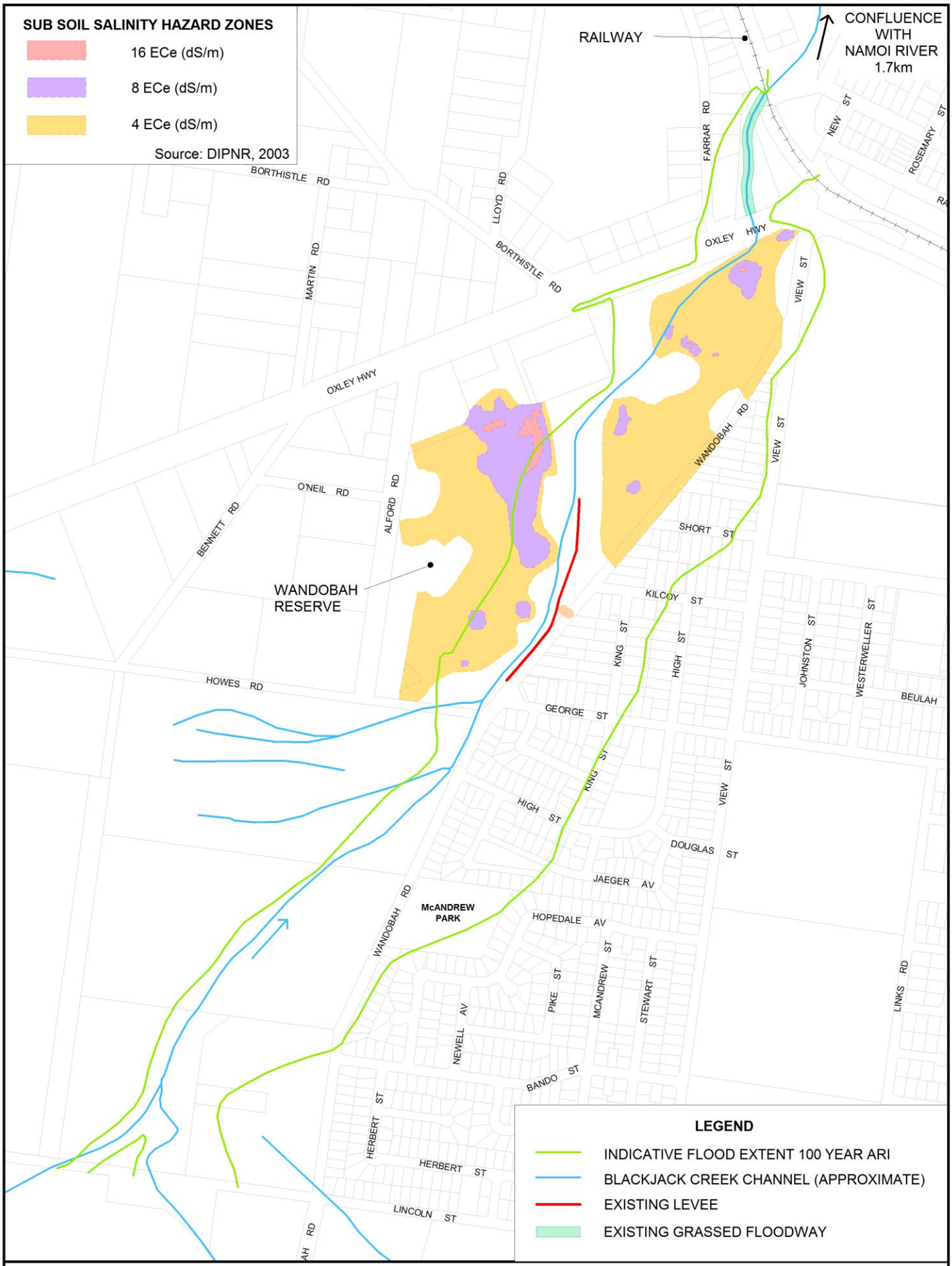
- **Appendix C** presents the responses of the Community Newsletter/Questionnaire.

1.4 Community Consultation

Following the inception meeting of the Floodplain Management Committee at Gunnedah, a Community Newsletter was prepared by the Consultants introducing the study and distributed to residents by Council. The Newsletter contained a Questionnaire seeking details from the community of flood experience and attitudes to potential floodplain management options. Community responses are summarised in **Section 3,** with further details in **Appendix C**.

At the inception meeting an inspection of the area was undertaken by the Consultants and Council representatives which assisted in gaining a good understanding of topographic conditions, historic flood behaviour and flooding issues.

A further meeting of the Committee was held to discuss technical features of the structural flood mitigation schemes and the suitability of measures for inclusion in the draft Plan. A draft Study report and a draft Plan (this document) were then prepared for submission to Council and public exhibition.



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BLACKJACK CREEK FLOODPLAIN RISK MANAGEMENT STUDY

Figure 1.1

LOCALITY PLAN

2 BASELINE FLOODING CONDITIONS

2.1 Catchment Description

The total catchment area of Blackjack Creek at the Oxley Highway crossing is about 24 km^2. The main arm of Blackjack Creek flows northwards over a distance of 8 km from the catchment boundary to the Highway. The catchment headwaters are quite steep, with natural surface levels falling from RL 670 m at the highest point near the south-west boundary to RL 284 m at Lincoln Street over a distance of 5.5 km and at an average gradient of 7 per cent. At Lincoln Street the stream flattens, with an average bed slope of 0.78 per cent over the remaining 2.5 km to the highway bridge. The floodplain in this reach averages about 300 m in width and comprises cleared overbanks on the western side and urban areas on the eastern side. Downstream of Lincoln Street, the stream runs parallel with and close to the western edge of Wandobah Road.

A levee bank (shown on **Figure 2.1**) has been constructed on the eastern bank between George Street and Short Street to contain flows which surcharge the hydraulic capacity of the channel. However, in the event of major flooding, the stream would break its banks further upstream between Lincoln Street and McAndrew Park and outflank the levee. During those events, Wandobah Road would act as a floodway and flooding would extend into the residential area on the eastern side of the road.

The waterway at the Oxley Highway crossing comprises 12 box culverts with a total width of 33.7 m and height of 1.5 m. The channel from the Highway to the railway comprises a grassed trapezoidal floodway of around 30 m width. The railway crossing comprises a three span bridge, with each span 8 m wide and about 2.5 m high.

Between the Oxley Highway and the railway culvert, a large rectangular shaped concrete drain joins the right bank of Blackjack Creek. This drain, known locally as Ashfords Watercourse, conveys runoff from the 3.2 km^2 catchment to the east of Blackjack Creek. Council assessed that peak flows from this catchment could reach 17-18 m^3/s in the event of major flooding. This discharge compares with a peak 100 year ARI discharge of 126 m^3/s crossing the Oxley Highway. As Ashfords Watercourse is likely to introduce a backwater effect and influence flood levels at the Oxley Highway, contributions to flow from that catchment were included in the hydraulic modelling of Blackjack Creek undertaken in the Flood Study, 2005.

The hydraulic modelling undertaken in the Flood Study, 2005 continued below the Oxley Highway to a point about 150 m downstream of the railway culvert. Major flooding from the Namoi River extends as far as the downstream side of the railway and therefore does not influence flood levels in the study area.

2.2 Flood History

A major storm occurred on 30 January 1984, which was reported by residents in responses to the Community Questionnaire to have resulted in inundation of the Blackjack Creek floodplain, with flows extending into the residential area on the eastern side of Wandobah Road and overtopping the Oxley Highway culvert. The peak flood level on the upstream side of the culvert was about 600 mm over the deck. Other significant floods are reported to have occurred in the wet years 1971 and 1976, but there are no quantitative data available for those events.

Based on an analysis of the Gunnedah pluviograph, over the three hours of the most intense burst of rainfall on 30 January 1984, a total depth of 82.5 mm was recorded compared with 90 mm for the 1 in 100 year rainfall of the same duration. For the 5 hour duration, a total depth of 106 mm was recorded, which exceeds the 1 in 100 year depth of 103 mm. Storms of between 3 and 6 hours duration were found to maximise peak flows on the Blackjack Creek catchment. Consequently, on the basis of recorded rainfall depths, the January 1984 storm was a 1 in 100 year event. In view of the heavy rainfall experienced over the preceding days, rainfall losses would have been much less than the average loss rates used in design flood estimation. It is possible that the peak discharge experienced would have exceeded the 100 year ARI design discharge.

A major storm was experienced on the Blackjack Creek catchment on 28 November 2008. Residents reported similar flood experiences to those experienced in 1984, although there were no reports of the Oxley Highway culvert being surcharged. A depth of 72 mm of rain was recorded at the pluviograph over the peak 3 hour period, equivalent to a 20 to 50 year ARI storm for that duration. Residents reported the occurrence of main stream flooding from the creek, as well as surcharges of the local piped stormwater system.

2.3 Characteristics of Flooding

2.3.1 Main Stream Flooding

Figure 2.1 shows the areas likely to be inundated by the 100 year ARI design storm and the PMF. The flood extents were originally determined in the 2005 Flood Study using the creek cross sectional survey used for hydraulic modelling, supplemented by 2 m interval ground surface contours and have been updated using natural surface levels in residential properties determined in the property survey used to assess flood damages (**Appendix B**).

The Blackjack Creek channel generally has a 5 year ARI capacity except in the immediate vicinity of George Street, where the creek is on the point of surcharging its banks and flooding Wandobah Road for that discharge. Larger floods break out in the McAndrew Park area and inundate the residential area on the eastern floodplain, with a progressive increase in extent as discharges increase. Flood flows continue to follow the line of the creek with increasing flood magnitude, with no new flow paths being created up to the PMF, which has peak levels about 1.9 m higher than the 100 year ARI flood at the highway and 1 to 1.5 m higher further upstream along the creek.

The extents of inundation shown on **Figure 2.1** are indicative only due to limitations in the accuracy of the available survey data and should not be used to assess the flood affectation or otherwise of individual properties. A site survey would be required to assess the degree of flood affectation of individual properties.

Because of the small size of the catchment and comparatively steep gradient of the creek, flooding is of a “flash flooding” nature and is usually of short duration. **Figure 2.2** shows the modelled rise of floodwaters at the Oxley Highway resulting from 20 and 100 year ARI design storms of 180 and 360 minutes durations. Floodwaters rise to a peak about 3 to 4 hours after the commencement of heavy rainfall.

Further details of the duration of high levels at other locations along the length of the creek are shown on **Figure 3.4**.

2.3.2 Local Catchment Flooding

Flooding also occurs in the residential area as a result of localised storms surcharging Council's stormwater drainage system. Numerous accounts of nuisance flooding from this source were reported by residents in their responses to the Questionnaire.

Council has recently prepared a numerical model of the piped stormwater system draining to Blackjack Creek from the eastern side of Wandobah Road using the DRAINS rainfall-runoff software. The results of modelling the system show considerable surcharge for major storms, confirming the responses of residents to the Questionnaire.

Details of the operation of the stormwater system are discussed in **Section 3.5** in connection with the completion of the protective levee along the western side of Wandobah Road. As noted therein, the main technical problem associated with the levee would be the capture and discharge of stormwater from the protected area over the duration of high water levels in the creek.

2.4 Flood Hazard Zones and Floodway Areas

2.4.1 Flood Hazard

Provisional flood hazard categories were assigned to flood affected areas in the Flood Study, 2005 in accordance with the procedures outlined in the *Floodplain Development Manual, 2005*. Flood prone areas may be provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity.

Flood depths as high as 1 m in the absence of any significant flow velocity represent *Low Hazard* conditions. Similarly, areas of flow velocities up to 2.0 m/s but with minimal flood depth also represent *Low Hazard* conditions. Interpolation may be used to assess hazards for intermediate values of depth and velocity. Flood hazards categorised on the basis of depth and velocity only are *provisional*. They do not reflect the effects of other factors that influence hazard. These other factors include:

- Size of flood – major floods though rare can cause extensive damage and disruption.
- Effective warning time – flood hazard and flood damage can be reduced by evacuation if adequate warning time is available.
- Flood awareness of the population – flood awareness greatly influences the time taken by flood affected residents to respond effectively to flood warnings. The formulation and implementation of response plans for the evacuation of people and possessions promote flood awareness.
- Rate of rise of floodwaters – situations where floodwaters rise rapidly are potentially more dangerous and cause more damage than situations in which flood levels increase slowly.
- Duration of flooding – the duration of flooding (or length of time a community is cut off) can have a significant impact on costs associated with flooding. The duration is shorter in smaller, steeper catchments.
- Evacuation problems and access routes – the availability of effective access routes from flood prone areas directly influences flood hazard and potential damage reduction measures.

Provisional hazard categories may be reduced or increased after consideration of the above factors in arriving at a final determination.

A qualitative assessment of the influence of the above factors on the provisional flood hazard on Blackjack Creek (i.e. the hazard based on velocity and depth considerations only) is presented in **Table 2.1**. Factors which would increase the flood hazard in **Table 2.1** are balanced by considerations reducing the hazard. Consequently, there would be no reason to adjust the provisional flood hazard and the determination of hazard in the floodplains could be based on depth and velocity alone.

TABLE 2.1
INFLUENCE OF FLOOD RELATED PARAMETERS ON PROVISIONAL FLOOD HAZARD IN BLACKJACK CREEK FLOODPLAIN

Parameter	Influence on Provisional Hazard	Flood Characteristics
Size of flood	0	Flooding is comparatively shallow, with no sudden increases in depth of flow or alternative flow paths developing with increasing severity of flooding for floods up to PMF.
Effective warning time	1	The warning time is short and presently limited to two or three hours, which would tend to increase the provisional flood hazard.
Flood awareness	-1	Flood awareness appears to be quite high due to the occurrence of a major storm in November 2008 and the record flood of January 1984 which was well remembered by residents in their responses to the Questionnaire.
Rate of rise and velocity of floodwaters	1	Flooding is of a "flash flooding" nature, with the stream rising to a peak within three to four hours of the commencement of heavy rainfall. This would tend to increase the flood hazard, although the hazard could be reduced by education the community about flood risk.
Duration of flooding	– 1	The duration of the flood peak is quite short, around two hours for the design storms shown on **Figure 2.2**.
Evacuation problems	– 1	There is easy evacuation from the residential area eastwards out of the flooded area to higher ground. Evacuees would not need to travel more than 200 m through rising ground to flood free land.

Legend 0 = neutral impact on provisional hazard
1 = tendency to increase provisional hazard
– 1 = tendency to reduce provisional hazard

Figure 2.3 shows hazard zones for the 100 year ARI flood. Three zones have been adopted in the final determination:

- The *High Hazard* zone extends over the eastern floodplain as far as Wandobah Road. In this area depths of flow would average 1.5 m and flow velocities would be between 1 and

1.5 m/s. This area comprises the channel of the creek and its immediate overbank areas and is undeveloped, grassed land with some tree cover.

- The *Medium Hazard* zone comprises portion of the residential area to the east of Wandobah Road where depths of inundation could reach 0.8 m but flow velocities would be low; around 0.1 to 0.2 m/s.

- The *Low Hazard* zone comprises the remainder of the area inundated by the 100 year ARI flood, where the depth of flooding would average 0.3 m but velocity would not be significant.

2.4.2 Floodways

According to the *Floodplain Development Manual, 2005*, the floodplain may be subdivided into the following zones:

- Floodways;
- Flood storage; and
- Flood fringe

Floodways are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if partially blocked, would cause a significant increase in flood level and/or a significant redistribution of flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

In determining appropriate hydraulic categories, it is important that the *cumulative* impact of progressive development be evaluated, particularly with respect to floodway and flood storage areas. Whilst the impact of individual developments may be small, the *cumulative* effect of the ultimate development of the area can be significant and may result in unacceptable increases in flood levels and flood velocities elsewhere in the floodplain.

In practice, development of flood liable areas bordering a stream usually proceeds from the shallower flood fringe areas towards the channel. The *Floodplain Development Manual, 2005* provides guidelines on determining the boundary between the floodway and flood storage zones using the hydraulic model and what may be termed “encroachments” into the floodplain. In this approach, conceptual vertical boundary lines are progressively moved into the floodplain from both sides thereby constricting the flow to the degree where peak flood levels and peak flows are increased anywhere

within the extent of the model by a specific amount. The FDM, 2005 suggests a limiting increase of 100 mm in peak flood levels and 10% in peak downstream discharges.

The portions of the floodplain on the landward side of the encroachment lines represent that part of the floodplain which may be removed both in terms of conveyance capacity and flood storage without causing excessive adverse impacts on flood behaviour. The locations of the encroachment lines on each side of the stream represent the boundary between the floodway and the flood storage or flood fringe zones.

Hydraulic categories were determined for this investigation in accordance with the "encroachment" procedure. The hydraulic analysis showed that an encroachment to Wandobah Road (i.e. removal of the conveyance capacity of the floodplain east of that line) could increase flood levels by up to 150 mm in the McAndrew Park area. This result indicated that the Flood Policy should ensure that future development does not block the passage of overland flows on the eastern floodplain to a greater extent than occurs at present. Consideration would need to be given to the type and siting of fences and filling incorporated in any new development. Accordingly, the hydraulic categorisation of floodplain adopted in this study comprises "Floodway," "Flood Storage" and "Flood Fringe" areas. **Figure 2.4** shows the resulting hydraulic categorisation for the 100 year ARI flood.

2.5 Impacts of Climate Change

CSIRO undertook investigations for the NSW Government (Hennessy et al, 2004) which indicated that whilst the region will become drier on average due to climate change, the frequency and intensity of climate extremes such as storms, floods and droughts will increase. That is, large flood producing storms will occur more often and be greater in magnitude. The investigations suggest that until 2030, there will be an increase in the 40 year ARI 24 hour rainfall of +3 per cent and an increase of +10 per cent by 2070.

DECCW recommends that its guideline *Practical Considerations of Climate Change, 2007* be used as the basis for examining climate change in projects undertaken under the State Floodplain Management program and the *Floodplain Development Manual, 2005*. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent.

On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit. Under present day climatic conditions, increasing the 100 year ARI design rainfall intensities by 10 per cent would produce a 200 year ARI flood; and increasing those rainfalls by 30 per cent would produce a 500 year ARI event.

An assessment on the impacts of flooding could be achieved by assuming that the above increases in rainfall directly translate to an equivalent increase in flood peak discharges. Assuming a 10 per cent increase, the 100 year ARI flood peak of 124 m^3/s would increase to 136 m^3/s at the Oxley Highway bridge. By interpolation of the water surface profiles derived from the hydraulic modelling, the resulting increase in peak water levels would be no greater than 100 mm. The 30 percent increase in flows would result in an increase of no more than 200 mm. Therefore the future effects of climate change, as far as peak flood levels are concerned, could be accommodated within the 500 mm of freeboard

which is usually applied to the best estimate of flood levels, with a reasonable margin remaining for other uncertainties such as local hydraulic effects and wave action.

The impact of climate change on *flooding patterns* in Blackjack Creek may therefore be summarised as:

- A gradual widening of the extent of inundation along the length of the main arm of Blackjack Creek.
- A small increase in flow velocities within the inundated area running along the main arm, but no sudden increase in the provisional flood hazard due to increased flood depths and flow velocities.
- No islands or new flow paths would be created. Flow would continue to follow its existing course along the valley of the creek.
- There may be a small reduction in the time of rise of the floodwaters. Blackjack Creek is flash flooding with only a few hours of warning time available to residents (**Figure 2.2**). Effective flood warning may not be achievable even with the benefit of future technical improvements in systems. Therefore on-going community education of the nature of flooding via Council and SES is required to limit risks to people and property.

2.6 Economic Impacts of Flooding

The economic consequences of floods are discussed in detail in **Appendix B**, which assesses flood damages to property in the floodplain, which are almost exclusively of a residential nature. There are no data available on historic flood damages to the residential sector in the study area. Accordingly it was necessary to use data on damages experienced as a result of historic flooding in other urban centres. The residential flood damages were assessed using techniques developed and tested in numerous urban and rural flood situations in NSW and based on the recent publication *Floodplain Guideline Number 4, 2007* published by DECCW. **Figure B8.3** of **Appendix B** identifies properties which would be subject to above-floor inundation in the event of the 100 year ARI flood. This diagram has been prepared after comparison of peak design flood levels derived with the floor levels obtained during the property survey used to estimate flood damages. The numbers of properties flooded above floor level are listed on **Table 2.2**.

TABLE 2.2
NUMBER OF PROPERTIES FLOODED
BLACKJACK CREEK STUDY AREA

Flood Event Year ARI	No. of Properties Flooded Above Floor Level		
	Residential	Commercial/ Industrial	Public Buildings
20	29	0	0
50	66	0	0
100	104	0	0
PMF	192	1	0

Note: These properties would experience flooding above floor level. Flood liable properties (100 year ARI) are shown on **Figure B8.3** of **Appendix B**.

Table 2.3 shows the damages experienced for each class of property.

TABLE 2.3
FLOOD DAMAGES IN BLACKJACK CREEK STUDY AREA

Average Recurrence Interval Year ARI	Flood Damages to Each Category ($ x 10^6)			Total Damage ($ x 10^6)
	Residential	Commercial	Public	
20	1.39	0	0	1.39
50	2.43	0	0	2.43
100	3.45	0	0	3.45
PMF	9.07	0.05	0	9.12

Significant flood damages would be experienced at the 20 year ARI level. A total of 29 residential properties would experience flooding above floor level. At the 100 year ARI, additional properties would be flooded. A total of 104 residences would experience flooding above floor level with the greatest depth being 900 mm in King Street. In the event of a PMF, 192 residences would be flooded above floor level.

2.7 Existing Flood Modification Measures (Structural Works)

There are no structural flood management measures currently in place for the Blackjack Creek catchment. A levee was constructed between George Street and Short Street, but as mentioned previously, it would be outflanked during major flooding by breakouts from the creek further upstream.

Following the January 1984 flood a Council commissioned the design of a channel scheme extending through Wandobah Reserve from Lincoln Street to the Oxley Highway. The scheme comprised a grassed trapezoidal channel with an invert width ranging between 17.5 and 20 m. The channel was designed to convey the 100 year ARI discharge, but was not constructed.

More recently, DIPNR (now DECCW) carried out geophysical investigations to locate salt affected areas for the purposes of channel reconstruction in the Wandobah Reserve (DIPNR, 2003). Mapping of soil hazard zones is presented in **Figure 1.1**. Council has relocated the proposed channel route so that it bypasses areas with the highest salinity and also takes into account the need to minimise disturbance to existing trees and native vegetation. The feasibility of constructing improvements to the channel along Council's preferred route, as part of the development of a riparian corridor on Blackjack Creek, is discussed in **Section 3.3** of this study.

2.8 Council's Existing Planning Instruments and Policies

Planning Instruments used by Gunnedah Shire Council to manage development in Blackjack Creek comprise the following documents:

- Gunnedah Local Environmental Plan, 1998 (Updated 20 July 2008).
- Development Control Plan "Principles of Development", 2004.

2.8.1 Land Use Zoning

The area east of Wandobah Road extending to View Street is zoned Residential 2(a).

The area bordering the creek west of Wandobah Road is variously zoned:
Special Uses 5(a) – the cemetery to the north of Lincoln Street.
Proposed Open Space 9(c) – Lincoln Street to Howes Road.
Open Space (Recreational) 6 – Howes Road to Oxley Highway including Wandobah Reserve.

On the western floodplain fronting the Oxley Highway there are also areas of:
Special Uses 5(a) and
General Industrial 4(a)

2.8.2 Flood Provisions of the Gunnedah LEP, 1998

Clause 3(7) of the LEP outlines its objectives relating to flooding:

> *"(a) to reduce the incidence and level of hazard to areas subject to flooding by managing development in the floodplain and floodways, and*
>
> *(b) to allow more detailed controls on development in the floodplain and in floodways to be provided in Council's Interim Flood Prone Lands Policy."*

The LEP nominates the conditions shown below for development of floodways or on flood prone land. The definitions of "floodway" and "flood prone land" in the LEP are inconsistent with the Glossary of the FDM, 2005. "Flood prone" land is identified in the LEP as land shown flooded on the Flood Inundation Map, dated 1978 and includes land that would be affected by the 1% AEP (100 year ARI) flood, whereas the true definition of flood prone land is land inundated by the PMF or the Extreme Flood. The Flood Inundation Map, 1978 relates to land flooded by the Namoi River. Until the preparation of the Flood Study, 2005, no information was available regarding the extent of flooding on Blackjack Creek.

Flood related clauses are contained in Clause 26 of the LEP entitled: "Is the development of flood prone land permitted by this plan?" and are presented below:

(1) A person must not erect a building or carry out a work for any purpose on flood prone land without the permission of Council.
(2) The Council must not consent to the erection of a building or carrying out of a work for any purpose on land that is flood prone unless it is satisfied that:
  (a) the building or work would not unduly restrict the flow characteristics of flood waters , and
  (b) the building or work would not unduly increase the degree of flooding on land in the vicinity, and
  (c) the structural characteristics of the building or work, the subject of the application, are capable of withstanding flooding, and
  (d) the proposed building is adequately flood proofed.
(3) The Council must not grant a consent required by this clause unless it has taken into consideration:
  (a) the cumulative effect of the building or work on flood behaviour, and

(b) the risk of pollution to the waterways caused by the building or work, and
(c) the availability of access to the building or work to ensure the timely, orderly and safe evacuation of people from the area should a flood occur.

(4) When granting such a consent, the Council may require each habitable floor of a building to be erected to a height which is sufficient, in its opinion, to obviate the frequent flooding of the building.

2.8.3 Flood- Related Clauses in Updated LEP

Gunnedah Council is currently in the process of updating its LEP in common with other Councils in NSW. DOP and DECCW have carried out extensive negotiations regarding the generic wording of flood related clauses to be included in new versions of LEP's in NSW.

The *provisionally* agreed (and subject to change) generic wording for new LEP's is shown below:

" 7.3 Flood planning [local d07]

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land;

(b) to allow development compatible with the land's flood hazard, taking into account projected sea level rise;

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land that is shown as "Flood Planning Area" on the Flood Planning Map, and

(b) other land at or below the flood planning level.

Drafting direction
Councils know of some areas that flood and those areas are mapped as "flood planning area", but there are other areas where accurate mapping is not possible. Consequently, the wording of this sub-clause captures the land that can be accurately mapped and the land that cannot. Such unmapped land includes the "flood planning area" (as defined in the Floodplain Development Manual) up to the "flood planning level".

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land; and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) will not be likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the NSW Government's Floodplain Development Manual published in 2005, unless it is otherwise defined in this clause.

(5) In this clause:

***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus [insert number 0.xx] metres freeboard.*

Flood Planning Map means the [Name] Local Environmental Plan 2010 Flood Planning Map. "

The ***flood planning level*** (FPL) referred to above is the 100 year ARI flood plus an allowance for freeboard, which is usually set at 500 mm. It is the minimum level set for future residential development. The area encompassed by the FPL is known as the Flood Planning Area and denotes the area subject to flood related development controls. It is now standard practice for the residential FPL to be based on the 100 year ARI flood plus freeboard unless exceptional circumstances apply (see **Section 3.6.2** for further discussion).

This wording recognises recent amendments to government policy that for residential land use, the area to be subject to flood-related development controls will be limited to land inundated by the 100 year ARI flood plus an allowance for freeboard.

Under the arrangements agreed to by DOP and DECCW, flood related development controls for other categories of development for which a higher level of protection may be required (e.g. hospitals, aged persons accommodation, critical utilities, etc), may be covered by Flood Policy DCP's.

2.8.4 Section 149 Certificates

Gunnedah Council currently use the Flood Study, 2005 results in setting minimum floor levels for residential property, based on the 100 year ARI flood level plus 500 mm freeboard.

Council provides flood related development information in S149 (2) certificates at Clause 7A therein. Wording is as follows:

"The subject land is identified as being subject to flooding in the Blackjack Creek Flood Study 2005. Development of the land should take into consideration the contents of the study. Clause 26 of the Gunnedah Local Environment Plan 1998 outlines the development controls for flood prone land. Refer to the attachment."

The "attachment" referred to in the above wording is a Schedule containing the following information:

- A statement of the aims and objectives of the NSW Government's Flood Policy, setting out the sequential stages of investigations leading to the preparation of the Floodplain Risk Management Plan for Blackjack Creek. (The statement is similar to that contained in the Foreword to this present study report.)

- A short summary of the aims, objectives and results of the Flood Study, 2005.

- A re-statement of Clause 26 of Gunnedah Local Environment Plan, 1998.

The proposed updating of Gunnedah Council's LEP will necessarily require an updating of the flood related wording in Council's S149 (2) Certificates, because Clause 26 will probably be amended to conform with the above wording agreed to by DOP and DECCW (**Section 2.8.3**). It is not possible at this time to propose amended wording, in view of the fact that the currently agreed wording is provisional.

However it is suggested that the new wording of S149 (2) certificates could be greatly simplified along the following lines:

"Based on flood investigations and mapping in Council's possession, this property may lie within the extent of the residential Flood Planning Area (land encompassed by the 100 year ARI flood level plus 500 mm) and is therefore subject to flood related development controls, which are set out in Council's Flood Policy and the Blackjack Creek Floodplain Risk Management Study, 2010. Further information may be obtained by enquiries of Council."

2.8.5 Council's Existing Flood Policy

Council's flood policy is set out in *Chapter 9* of *Part 3 - Planning Issues* of the DCP entitled *"Principles of Development"*. The policy follows the recommendations of the *Gunnedah and Carroll Floodplain Management Study* prepared by SMEC, 1999 and deals with main stream flooding from the Namoi River.

In keeping with modern flood policy, the flood policy structures the criteria to be adopted for assessing proposals which are potentially affected by flooding in recognition that different controls are applicable to different land uses and levels of potential flood inundation and hazard. The policy recognises two types of hydraulic conditions:

*"**Floodway**. The policy recognises these are areas subject to high hazard conditions where inappropriate development could result in an obstruction to the flow of floodwaters, which in turn leads to an increase in flooding elsewhere and increases the susceptibility for damage and risk to lives. The policy states that whilst existing developments may require minor alterations or improvements to the land (which would be permissible subject to controls) intensification of land use should not be encouraged. Accordingly the following conditions would apply to applications for development in the floodway:*

(a) no new buildings shall be permitted;

(b) filling shall not be permitted in a floodway other than in conjunction with riverbank rehabilitation and stabilisation provided that the levels do not protrude above natural surface levels;

(c) fences shall not be permitted except where it can be demonstrated to Council that they are essential in which case they must be of post and rail strand wire or shear connectors construction; and

(d) no further intensification of floodways shall be allowed unless it relates to the conversion of floodways to natural waterway corridors.

***Flood Fringe**. Applications will need to satisfy the following conditions:*

Floor levels

Habitable floor levels of residential property to be equal to or greater than 1% AEP flood plus 0.5 m freeboard.

There is no minimum floor level for commercial properties. Property owners should consider issues of streetscape and access in conjunction with flood risk when proposing floor levels. However, where floor levels are below the 1% AEP flood level a Site Specific Response Plan must accompany the application to show that areas are available for the temporary storage of hazardous materials and valuable goods above the 1% AEP flood level plus 0.5 m freeboard.

Critical utilities and public facilities should have floor levels equal to or greater than the extreme flood event (defined as a flood with discharge equal to 3 times the 1% AEP flood) plus 0.5 m freeboard, or be protected from the extreme flood by other measures such as a levee.

Building Components and Materials

Any portion of the building constructed below the Flood Planning Level for that class of development must be constructed of flood compatible materials.

Structural Soundness

Applicants are to demonstrate that any structure subject to flooding should withstand the forces of floodwater, debris and buoyancy. For residential and commercial/ industrial development the design flood for this clause is the 1% AEP event and for critical utilities and public facilities it is the extreme flood.

Flood Effects on Others

Council may require a report on the impact of the development on local flooding patterns.

Evacuation and Access

Development will only be permitted where effective warning time and reliable access are available for the evacuation of flood prone land."

2.8.6 Suggested Amendments to Flood Policy

The amendments set out below would allow the existing Flood Policy developed by Council following the SMEC, 1999 study to apply for Blackjack Creek, as well as conform with the more recent requirements of the Circular issued by the Department of Planning on 31 January 2007. That Circular contained a package of information clarifying flood related controls on land located above the 100 year ARI flood level (i.e. land which is infrequently flooded).

The amended Flood Policy would be consistent with the flood related clauses in the new LEP agreed to by DOP and DECCW (see **Section 2.8.3**) and is supported by the results of the Flood Study, 2005

and the present investigation, which together have defined flood levels, flood extents and the hydraulic and hazard categorisation of the floodplain.

The suggested sub-division of the floodplain into hazard zones for the purposes of future development is shown on **Figure 2.5**, as follows:

- ***Floodway***. This zone is analogous the Floodway zoning for the Namoi River adopted in Council's Flood Policy and would define the area conveying most of the flow in Blackjack Creek. Within this zone conditions (a) to (d) of **Section 2.8.5** above would apply, as is the case for areas inundated from river flooding.

- ***Intermediate Floodplain***. This would be a new zoning not presently identified in Council's Flood Policy. It represents areas on the eastern side of Wandobah Road where flow velocities may be significant during major floods. Obstructions to the passage of flow may result in a re-direction of floodwaters to neighbouring property. In this zone there would need to be restrictions on fences and other potential flow obstructions such as site filling. Suggested wording which could be used by Council is given below.

- ***Flood Fringe***. This zoning is presently used in Council's Flood Policy to identify areas outside the floodway. On Blackjack Creek it would represent the remaining area which would be inundated by the 100 year ARI flood. Flooding may reach up to about 300 mm in depth but flow velocities would not be significant. Only floor level controls would apply in this zone.

- ***Outer Floodplain***. This would represent the zone between the 100 year ARI extent and that of the PMF. No controls over residential property would apply, but Council would check development proposals to ensure that the required freeboard on 100 year ARI flood levels was achieved. Otherwise, the situation may apply where properties just outside the extent of the 100 year ARI flood had floor levels lower than properties within that extent. The need for the check arises because the existing standard of mapping does not allow the line defining the *Flood Planning Area* (100 year ARI plus 500 mm) to be accurately identified. (This situation could be rectified by Council commissioning a survey to identify the extent of the *Flood Planning Area* between Lincoln Street and the Oxley Highway.)

The PMF flood levels should be used to control critical utilities and vulnerable development on Blackjack Creek instead of "*extreme flood levels",* as the latter term is relevant to Namoi River flooding. The **"Evacuation and Access"** Clause in Council's current Flood Policy (**Section 2.8.5**) is relevant to Namoi River flooding and should not be used to preclude development in areas of Blackjack Creek floodplain other than Floodway areas, because of the ready access out of that floodplain.

Suggested Additions to Council's Flood Policy to Cater for Fences and Filling in Intermediate Floodplain

A. Fencing

"Any proposed fencing is to be shown on the plans accompanying a development application to allow Council to assess the likely effect of such fencing on flood behaviour. Fences which minimise

obstructions to flow should be adopted. Where impermeable fences such as Colorbond, galvanised metal, timber or brush are proposed, fencing panels should be either:

a) removable so that panels can be laid flat; or

b) horizontally hinged where a portion of at least 1.2 m high is capable of swinging open to allow floodwater to pass."

B. Filling

"Building pads up to 1 m high are permitted for residential blocks. Not more than 50% of the width of the allotment at right angles to the direction of flow (which generally follows the direction of Wandobah Road) is to be impeded by fill. Subsurface drainage of building pads is required."

2.9 Flood Warning and Flood Preparedness

2.9.1 Gunnedah SES Local Flood Plan

The State Emergency Service is nominated as the principal combat and response agency for flood emergencies in NSW. The SES is responsible for the issuing of relevant warnings (in collaboration with the Bureau of Meteorology), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact.

The *Gunnedah Local Flood Plan, 2002*, published by SES covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding within the Gunnedah area. The *Flood Plan* is administered by the Gunnedah SES Local Controller who controls flood operations within the Gunnedah Shire Council area, which is itself located within the Namoi SES Division.

The *Local Flood Plan* covers the Gunnedah Shire Council area, which includes the urban centre of Gunnedah, surrounding villages and rural land. The Flood Plan is divided into the following parts:

- ***Preparedness***, the *Local Flood Plan* devotes considerable attention to flood alert and emergency response procedures to be followed in the event of imminent dam failure.

- ***Response***. The Gunnedah SES maintains an operation centre at the Local SES Headquarters in Bennett Road, Gunnedah. The Bureau of Meteorology, Namoi SES Division headquarters, Gunnedah Shire Council and State Water's Keepit Dam Office are identified as Sources of Flood Intelligence. The BOM provides Flood Watches giving an early appreciation of developing meteorologic situations which could lead to flooding. They are provided on a whole of catchment basis for the Namoi River valley. The BOM also provides Flood Warnings which include Namoi River height readings and height-time predictions at Gunnedah. The SES also monitors the potential problem areas such as low points on roads, bridges, creeks and flood runners. However, there is no mention of roads being overtopped or details of flooding in the Blackjack Creek catchment.

- ***Recovery,*** involving measures to ensure the long term welfare for people who have been evacuated, recovery operations to restore services and clean up and de-briefing of emergency management personnel to review the effectiveness of the Plan.

2.9.2 Incorporation of Blackjack Creek Flood Data in the Gunnedah Local Flood Plan

The *Local Flood Plan* deals with main stream flooding in the Namoi River and its tributaries and contains no specific mention of flooding problems in Blackjack Creek.

SES should review the *Local Flood Plan* after the completion of this study to take into account information contained on the impacts of flooding on urban development bordering Blackjack Creek, as well as recommendations regarding flood warning and community education. The following information will be of assistance in this regard:

- Indicative extents of inundation and areas subject to high hazard during major floods (**Figures 2.1** and **2.3**).
- Typical times of rise of floodwaters (**Figure 2.2**).
- Locations of residential properties inundated by floodwaters of various recurrence intervals and depths of above floor flooding (**Figure B8.3**).
- Inundation of local access roads.
- Information on the operation of the local stormwater system (see **Chapter 3**).

The *Local Flood Plan* should also recognise that the flooding which occurs within the Blackjack Creek urban area is of a "flash flooding" nature in contrast with the slow rising nature of flooding on the Namoi River.

2.10 Environmental Considerations

Mining along the Blackjack Creek corridor has resulted in erosion of the channel and salinity problems in the groundwater due to leaching from the saline-sodic soils due to extended wet periods. The Gunnedah Community Charrette held in 1997 made several proposals to mitigate adverse impacts including:

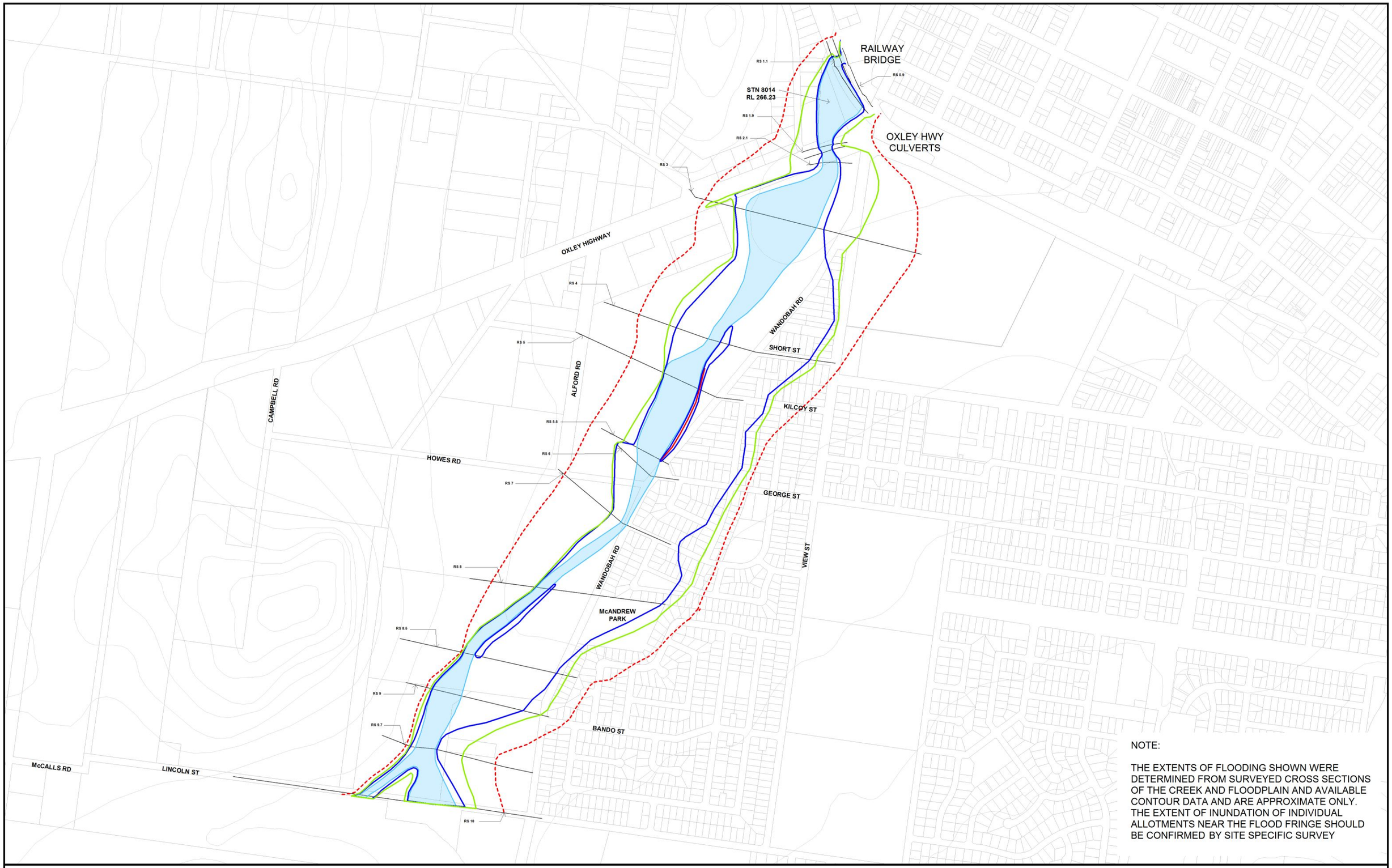
- The development of several shallow basins along the corridor to increase its capacity for storm water retention of runoff.

- Improvement of water quality and downstream ecosystems.

- Re-foliation of hillsides and planting of vegetation to absorb surface water and filter pollutants from surface runoff.

These suggestions were to be integrated with the overall design of the "continuous green space plan" aimed at improving the environment as well as providing recreational linkages to south-western Gunnedah and the koala habitat.

Subsequently the then DIPNR (now DECCW) undertook testing of soil salinity and mapping of problem areas in the Wandobah Reserve area. This work allowed the route of proposed improvements to the hydraulic capacity of the creek to bypass the most affected areas (**Chapter 3**).



NOTE:

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE SHOULD BE CONFIRMED BY SITE SPECIFIC SURVEY

N

200 0 200 400 600m

Scale: 1:10,000

NOTE: CROSS SECTION LOCATIONS EXTRACTED FROM STEWART SURVEYS CONSULTING SURVEYORS (NOV/04)

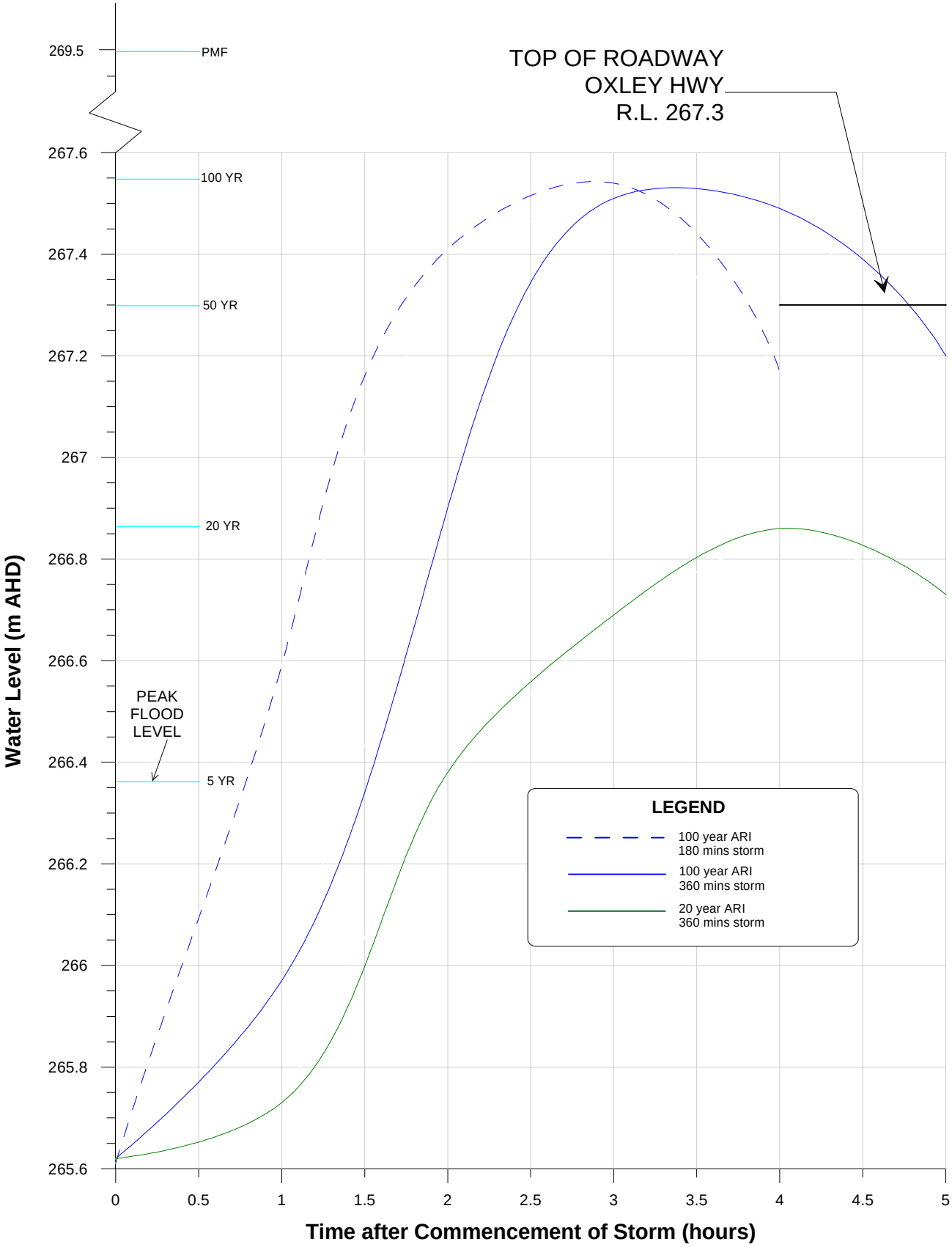
LEGEND

- 5 year ARI Flood Extent
- 20 year ARI Flood Extent
- 100 year ARI Flood Extent
- PMF Flood Extent
- RS 9 — Cross Section Location and HEC-RAS Model River Station Number
- Existing Levee

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 2.1

INDICATIVE EXTENTS OF FLOODING
5, 20, 100 YEAR ARI AND PMF



BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 2.2

TIME OF RISE OF FLOODWATERS AT OXLEY HIGHWAY

NOTE:

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE SHOULD BE CONFIRMED BY SITE SPECIFIC SURVEY

N

200 0 200 400 600m

Scale: 1:10,000

NOTE: CROSS SECTION LOCATIONS EXTRACTED FROM STEWART SURVEYS CONSULTING SURVEYORS (NOV/04)

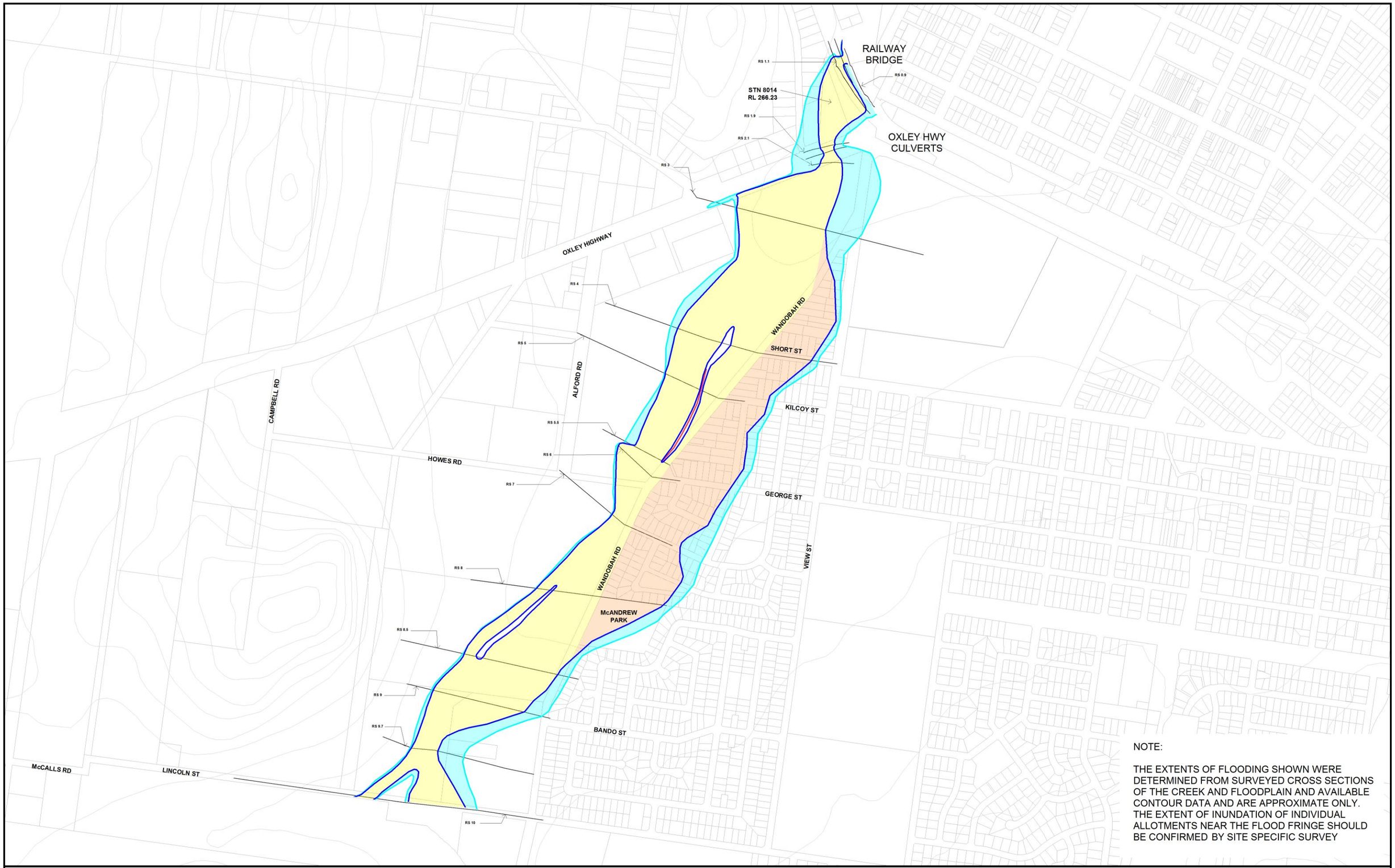
LEGEND

- 100 year ARI High Hazard
- 100 year ARI Medium Hazard
- 100 year ARI Low Hazard
- 100 year ARI Flood Extent
- RS 9 — Cross Section Location and HEC-RAS Model River Station Number
- Existing Levee
- 20 year ARI Flood Extent

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 2.3

FLOOD HAZARD ZONES 100 YEAR ARI



NOTE:

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE SHOULD BE CONFIRMED BY SITE SPECIFIC SURVEY

N

200 0 200 400 600m

Scale: 1:10,000

NOTE: CROSS SECTION LOCATIONS EXTRACTED FROM STEWART SURVEYS CONSULTING SURVEYORS (NOV/04)

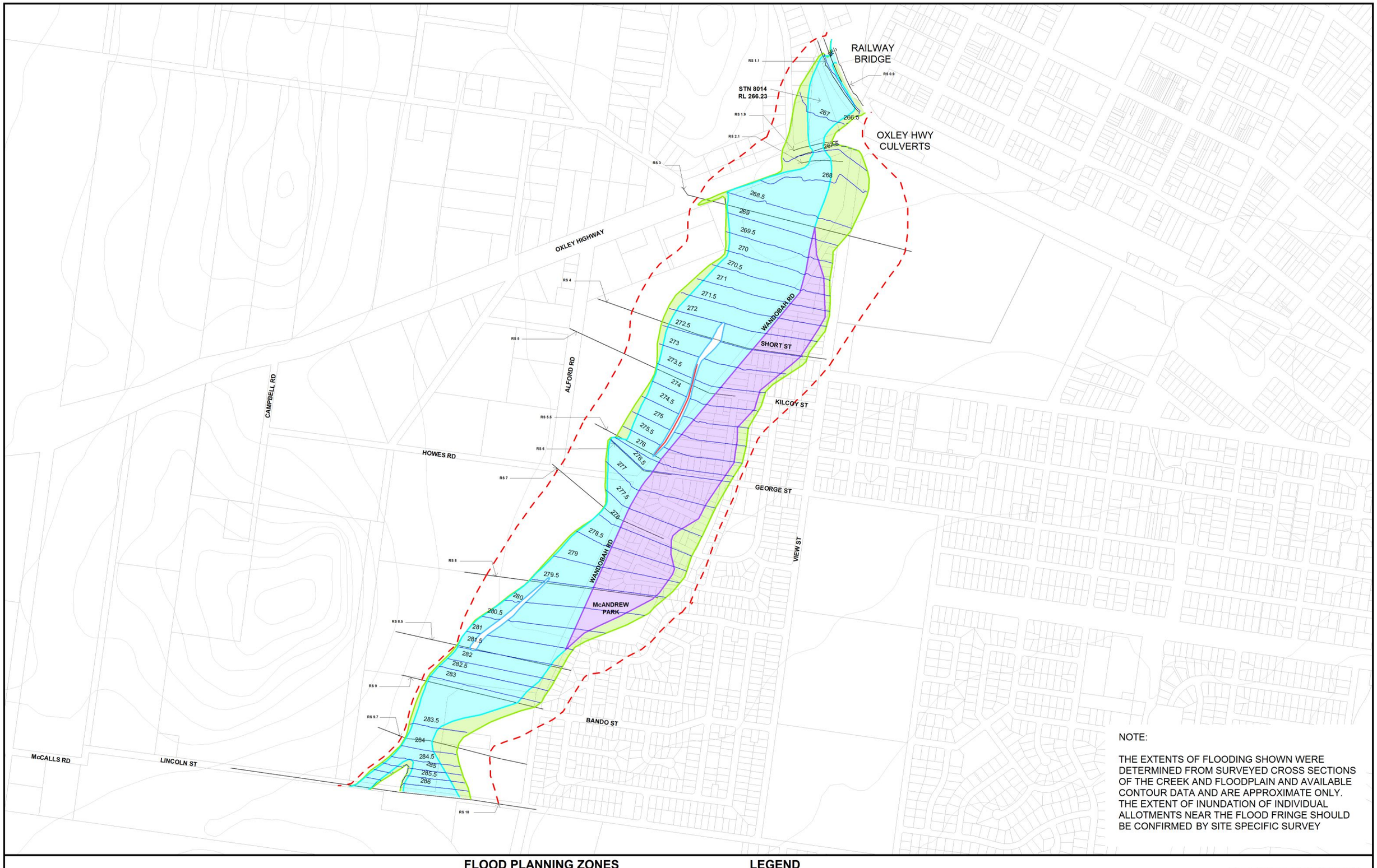
LEGEND

- 100 year ARI Floodway Extent
- 100 year ARI Flood Storage Area
- 100 year ARI Flood Fringe
- 100 year ARI Flood Extent
- RS 9 — Cross Section Location and HEC-RAS Model River Station Number
- Existing Levee
- 20 year ARI Flood Extent

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 2.4

HYDRAULIC CATEGORISATION OF FLOODPLAIN 100 YEAR ARI



NOTE:

THE EXTENTS OF FLOODING SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE SHOULD BE CONFIRMED BY SITE SPECIFIC SURVEY

N

200 0 200 400 600m

Scale: 1:10,000

NOTE: CROSS SECTION LOCATIONS EXTRACTED FROM STEWART SURVEYS CONSULTING SURVEYORS (NOV/04)

FLOOD PLANNING ZONES

- Floodway
- Intermediate Floodplain
- Flood Fringe
- Outer Floodplain

LEGEND

- RS 9 — Cross Section Location and HEC-RAS Model River Station Number
- Existing Levee
- Flood Contours (100 year ARI)

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 2.5

FLOOD INUNDATION AND FLOOD PLANNING ZONES

3 POTENTIAL FLOODPLAIN MANAGEMENT MEASURES

3.1 Range of Available Measures

A variety of floodplain management measures can be implemented to reduce flood damages, as follows.

Flood modification refers to changing the behaviour of floods in regard to discharges and water surface levels to reduce flood risk. This can be done by the construction of levees, retarding basins and channel improvements. Such measures are also known as "structural" options as they involve the construction of engineering works.

Property modification refers to reducing risk to properties through measures such as land use zoning, minimum floor level requirements, or house raising. Such options are largely planning measures, as they are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. Property modification measures could comprise a mix of structural and non-structural methods of damage minimisation.

Response modification refers to changing the response of flood affected communities to the flood risk by increasing flood awareness by the installation of flood warning systems and the development of emergency management plans for property evacuation. These options are wholly non-structural.

3.2 Community Views

Comments on potential flood management measures were sought from the local community by way of the Newsletter and Questionnaire distributed at the commencement of the study. The responses are summarised in **Appendix C.** Question 11 in the Questionnaire outlined a range of potential flood management options. The responses are shown on **Table 3.1**, together with initial comments on the feasibility of the measures, which are discussed in more detail in later sections of this Chapter.

The Community favoured the following measures:

- Management of vegetation in Blackjack Creek to maximise hydraulic capacity.
- Enlarging the channel to increase hydraulic capacity.
- Detention basins to store floodwaters and reduce downstream flood peaks.
- Construction of a levee along the eastern side of the creek to protect residential development.
- Controls over future development in flood liable areas.
- Improved flood warning, evacuation and flood response procedures, including evacuation and emergency assistance.
- Community education to promote flood awareness in the community.
- Provision of Flood advice certificates for properties located within the Flood Planning Area.
- Flood markers to show the extent and height of potential flooding.

These measures and the others included in the Questionnaire were examined at the strategic level of detail in **Chapter 3** and tested for feasibility on a range of assessment criteria in **Chapter 4.** Following consideration of the results by the Floodplain Management Committee, favoured measures were included in the draft *FRMP* in **Chapter 5**.

TABLE 3.1
COMMUNITY VIEWS ON POTENTIAL FLOOD MANAGEMENT MEASURES

Flood Management Measure		Classific -ation	Respondents' Views		Comments
			Yes	No	
a)	Maintenance programs to clear creek of vegetation and debris impeding flows.	FM	48	2	This option is strongly favoured by the Community and is reviewed in **Section 3.3**. It is not strictly a flood mitigation scheme as the hydraulic capacity of the channel would not be significantly increased and peak flood levels reduced; but it would have environmental benefits.
b)	Enlarge the Creek Channel	FM	38	3	This option is strongly favoured by the Community. The feasibility of this option is reviewed in **Section 3.3**. The augmenting the hydraulic capacity of the culverts beneath the Oxley Highway is also considered.
c)	Construct detention basins to store floodwaters.	FM	16	8	The community favours implementing detention basins on the creek to mitigate existing flooding problems. The feasibility of constructing basins to reduce downstream flood peaks is considered in **Section 3.4**.
d)	Construct permanent levees to contain floodwaters.	FM	27	8	This option is strongly favoured by the Community. The feasibility of providing a levee along the creek to contain floodwaters is considered in **Section 3.5**.
e)	Voluntary purchase of residential property within 100 year ARI flood extent.	PM	11	11	The community is evenly divided on this option, which is often adopted to remove residential property in high hazard areas of the floodplain. This option is reviewed in **Section 3.7**.
f)	Provide funding or subsidies to raise houses above 100 year ARI flood level.	PM	16	12	The community is evenly divided on this option. House raising is applicable to timber framed residences only, usually located in low hazard zones. This option is reviewed in **Section 3.8**.
h)	Controls on future development in flood-liable areas. (eg controls on location in the floodplain, minimum floor levels. etc.)	PM	25	3	Controls over development in flood prone land are very strongly supported by the community and would be an essential part of the FRMP. This issue is covered in the suggested development controls in **Section 3.6**.

Legend: FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option

TABLE 3.1
COMMUNITY VIEWS ON POTENTIAL FLOOD MANAGEMENT MEASURES
(Continued)

Flood Management Measure		Classification	No of Respondents		Comments
			Yes	No	
i)	Improve flood warning and flood response procedures	RM	33	3	There is presently no formal flood warning system for the creek, where flooding is of a "flash flooding" nature, with sudden rises in water levels after the onset of heavy rainfall. Improvements in flood warning procedures would be strongly supported by the community and are considered in **Section 3.9**.
j)	Improve evacuation and emergency assistance plans	RM	21	6	Emergency management in Gunnedah is covered by the SES's Gunnedah Local Flood Plan. Improvements would be strongly favoured by the community.
k)	Community education, participation and flood awareness programs	RM	30	2	Promotion of awareness of the flood risk would be strongly favoured among the community. This option is reviewed below.
l)	Provide a certificate to all residents stating whether their property is flood affected and to what extent	RM	32	1	Provision of information on flood affection of properties would be strongly favoured by the community. This is currently achieved by notation of flood affectation of allotments on Section 149 Certificates. This option is reviewed in **Section 3.6**
m)	Install flood markers	RM	26	3	This option probably as part of an integrated flood awareness program combining options k) and l) above would be favoured by the community.

Legend: FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option

3.3 Flood Modification Measures – Channel Improvements

3.3.1 Introductory Remarks

The hydraulic capacity of a stream may be increased by widening, deepening or straightening the channel and by clearing the banks of obstructions. The scope of such improvements can vary from minor works such as de-snagging and bank clearing, which do not increase the waterway area but reduce hydraulic roughness, to major channel excavations. Careful attention to design is required to ensure stability of the channel is maintained and scour or sediment build-up is minimised. The potential for channel improvements to increase downstream flood peaks also needs to be considered. In general, channel improvements need to be carried out over a substantial stream length to have any significant effect on flood levels. Proposals also need to conform with Government Policies in regard to retention of native vegetation, maintenance of fish habitat and other environmental considerations.

3.3.2 Management of Vegetation and Stream Clearing

The existing channel of Blackjack Creek is relatively indistinct and of low hydraulic capacity. It is capable of containing only minor flood flows. Under major flooding conditions most of the flow is conveyed on the floodplain, extending over Wandobah Road into the residential area on its eastern side, as well as onto the grassed, western floodplain.

Hydraulic modelling was undertaken to assess the reductions in peak flood levels which could be achieved by clearing the stream and reducing the height of vegetation on the western floodplain. The waterway area would not be increased by excavation, but any reduction in water levels would be achieved by a reduction in the resistance to flow (that is, a reduction in the “hydraulic roughness” of the natural surfaces in contact with the floodwaters).

The modelling showed that stream clearing (which would require continuing maintenance to remain effective) would not result in reductions in flood level greater than about 200 mm and therefore would not be a viable mitigation measure for major floods, although it would have environmental benefits and could possibly be justified on those grounds. Any program of vegetation management would need to be continually maintained to achieve the modelled reductions in flood levels.

3.3.3 Channel Improvements

Following the January 1984 flood, Council commissioned the design of a channel improvement scheme aimed at containing major floods up to the 100 year ARI level (Kelley and Associates, 1984). The scheme involved the construction of a grassed floodway of trapezoidal cross-section, with a low-flow concrete invert. The proposed floodway was not constructed, but would have extended over a 2 km reach from a point about 600 m downstream of Lincoln Street to the Oxley Highway.

The proposed cross section had a bed width of 20 m and 1 vertical to 5 horizontal side slopes and was sized for to contain the 100 year discharge, which was estimated at the time as 90 m^3/s. That discharge approximated the hydraulic capacity of the culvert at the Oxley Highway, which had been designed by the then DMR (now RTA) to convey up to 80 m^3/s without surcharging. No enlargement of the culverts beneath the Oxley Highway was proposed. The peak depth of flow and velocity in the channel were estimated at 1.2 m and 3 m/s respectively. The hydraulic roughness value adopted in the design of the channel was 0.029. This value is characteristic of a very hydraulically efficient, grassed channel and would have required a rigorous and continuing program of maintenance to remain as hydraulically smooth as was assumed in the design.

The more recent Flood Study, 2005 assessed the peak of the 100 year ARI discharge at 126 m^3/s at the Oxley Highway, which is about 30 per cent greater than Kelley and Associates' estimate of that flood peak. The models developed in the Flood Study were verified using historic flood data and consequently, are likely to have produced a more accurate estimate of the 100 year ARI discharge than the discharge adopted by Kelley and Associates. Consequently, a larger waterway area would be required to contain the 100 year ARI flood than was adopted in their design.

Over the last 20 years there has been a move away from achieving channel improvements by relatively straight, engineered grassed floodways, to designs more in keeping with the appearance and morphology of natural streams. More recently, the Department of Water and Energy (DWE), now DECCW, has noted that construction in the bed of streams or within 40 m of the banks would be regulated by the Water Management Act, 2000 and that approval for works would be required. It is likely that a design similar to the Kelley and Associates' concept would not be supported by DECCW, or the Namoi Catchment Management Authority for environmental reasons.

Modern practice is to consider creeks as functioning as riparian corridors and recognise that they form a transitional zone between terrestrial and aquatic environments, performing a range of important environmental functions, in addition to conveying flood flows.

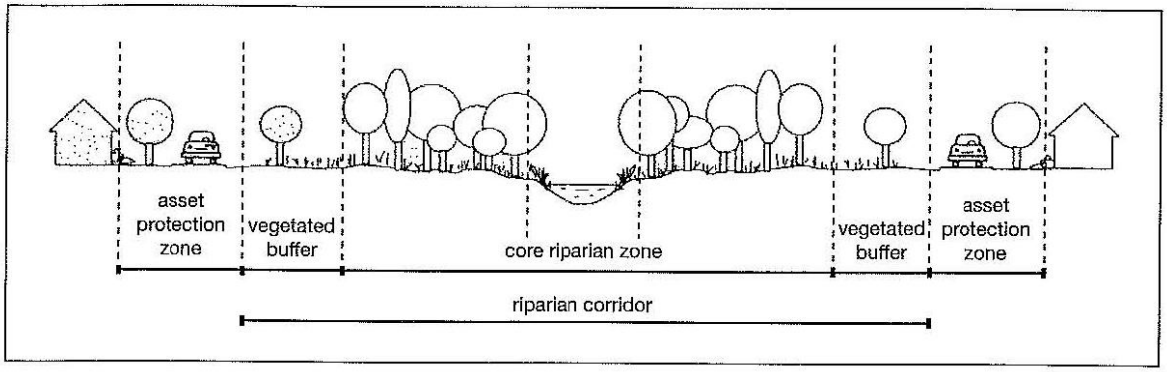
As noted in *DWE's Guidelines for Riparian Corridors, 2008* the functions are:

- Provide bed and bank stability and reduce channel and bank erosion.
- Protect water quality by trapping sediment nutrients and other contaminants.
- Provide a diversity of habitat for terrestrial riparian and aquatic flora and fauna species.
- Allow for the conveyance of flood flows and control their direction.
- Provide an interface between developments and waterways.

As shown on the schematic cross section Figure 1, extracted from DWE, 2008 a riparian corridor would typically comprises three zones:

- The core riparian zone (CRZ) contained within and adjacent to the channel.
- A vegetated buffer protecting the CRZ from weed invasion.
- An asset protection zone protecting houses from bushfire damage.

Figure 1. Riparian corridor zones.



3.3.4 Potential for Riparian Corridor/Improved Channel on Blackjack Creek

Blackjack Creek is a typical ephemeral stream with long dry periods and intermittent surface runoff events and occasional major flood flows such as occurred in January 1984 and November 2008. In view of the proximity of development on the eastern floodplain, mitigation of flooding would probably be a more important objective of the development of the riparian corridor than on other streams which do not have urban flooding problems. In order to achieve a flood mitigation objective, the overall hydraulic capacity of the waterway would need to be substantially increased.

As the vegetated zones on the floodplain associated with a riparian corridor on Blackjack Creek may result in an increase in hydraulic roughness compared with the existing grass cover on the floodplain, there will need to be a large increase in the area of the channel to contain floodwaters. Consideration will need to be given to limiting the density of planting in the area bordering the channel to ensure that flood levels for the very large events which surcharge the channel are not increased, compared with present day conditions. Because of the comparatively steep slope of the creek (averaging about 0.8% between Lincoln Street and the Oxley Highway) it would be desirable to vary the bed gradient and also provide a sinuous channel (in plan) more in keeping with natural streams, with occasional sections of transverse rock banking across the invert for the creation of ponds and control of bed scour.

Hydraulic modelling was carried out of a riparian corridor involving the above features. The objective was to contain the extent of flooding up to the 100 year ARI event to the confines of the channel. The channel would follow a route which had been previously been determined by Council to minimise impacts on existing trees and native vegetation and is shown on **Figure 3.1**. For the purposes of modelling the improved channel section was assumed to extend from model cross section RS9.7 about 200 m downstream of Lincoln Street, to RS3 a similar distance upstream of the Oxley Highway. Between cross sections RS3 and RS2.1 the channel invert would “tail out” to existing levels. The existing waterway area in the section of creek from RS3 to the Oxley Highway would not be increased, as flood levels in this reach are largely controlled by the hydraulic capacity of the road crossing. It is not proposed to increase the number of culverts elements. Under 100 year ARI conditions the roadway would be overtopped for a short time, as occurs at present.

From **RS 9.7** to **RS8** a trapezoidal channel of 20 m bed width and 1 vertical to 4 horizontal side slopes was modelled. Downstream of **RS8** a 30 m wide channel was modelled, to cater for the increase in flows from the local residential sub-catchments on the eastern side of the creek. Typical modelled cross sections are shown in **Figure 3.2**.

In practice the side slopes would be varied along the length of the channel to mimic natural streams. The invert and batters would be vegetated with local grass and plant species, selected and planted at a density which ensures that hydraulic capacity is not reduced over time. On-going maintenance would be required to control growth. Five or six rock structure would be located in the invert to control scour and allow the formation of ponds during dry periods. The overbanks would be planted with stands of trees to simulate natural creek conditions.

3.3.5 Indicative Cost of Riparian Corridor/Improved Channel

Table 3.2 provides an indicative capital cost of the riparian corridor scheme. For preliminary costing a 20 m width along each bank was adopted as the riparian corridor/vegetated buffer of Figure 1 of DWE’s Guidelines for Riparian Corridors, 2008.

The costing shown in **Table 3.2** has been developed using existing sources of survey data. This is appropriate for a strategy study such as the present *FRMS*, where the principal objective is to evaluate projects on a comparative basis. However, in order to gain Government funding, it would be necessary to refine the analysis and costing using more detailed survey and cost data. A concept design study is proposed as a project for inclusion in the draft *Floodplain Risk Management Plan* for Blackjack Creek. Concept design studies, along with the preparation of detailed designs quality for Government funding, along with the construction of the works.

Annual maintenance costs amounting to 1.5 percent of the capital cost have been converted to a present worth value and added to the capital cost to obtain an indicative total cost of the scheme, which has been used in the economic analysis of **Section 3.3.6**.

TABLE 3.2
INDICATIVE CAPITAL COST RIPARIAN CORRIDOR/IMPROVED CHANNEL

Item	Cost $
Preliminaries (Establishment, Geotechnical Testing, Sediment Control)	15,000
Clear and Grub Floodplain	170,000
Strip and Store Topsoil for later re-use on excavated surfaces	138,000
Excavate Channel over 1.9 km reach , spread spoil on floodplain	438,000
Spread stored topsoil over excavated surfaces	149,000
Sow and maintain native plants/grasses over excavated channel batters	252,000
Grass seed channel invert	250,000
Supply and place rock in channel invert to form rock pools and control scour	90,000
Riparian Zone plantings along channel overbanks (20 m each side)	133,000
Survey, investigation and design (7.5%)	123,000
Un-estimated items and contingencies (20%)	352,000
TOTAL ESTIMATED CAPITAL COSTS	**$2.1 M**

3.3.6 Economic Assessment of Riparian Corridor/Improved Channel

Surcharging of the channel of Blackjack Creek commences at the 5 year ARI and significant damaging flooding occurs at the 20 year ARI level of flooding in the residential developments bordering the creek. From the economic assessment of flooding presented in **Appendix B**, the *present worth value* of damages for all floods up to the 100 year ARI magnitude is $2.02 Million for a 7 per cent discount rate and over an economic life of 20 years. In an economic analysis, the damages prevented by a flood mitigation scheme represent its benefits. Therefore, provided damages up to the 100 year ARI level of flooding were eliminated by the proposed scheme, expenditure of the above amount could be economically justified.

Table 3.3 shows the results of the economic analysis. The analysis has been carried out for the three discount rates nominated by NSW Treasury Guidelines for the economic analysis of public works. The table includes an allowance for annual maintenance costs of 1.5 percent of the capital cost brought

back to a present worth value over a period of 20 years. The total indicative cost is about $2.44 Million, The benefit/cost ratio of the riparian corridor scheme is less than 1.

However, the scheme would protect the residential area against main stream flash flooding up to the 100 year ARI. It would mitigate main stream flooding in approximately one hundred residential properties which presently would be flooded in the event of a 100 year ARI flood. Therefore, the scheme would have considerable social benefits in terms of a reduction in flood risk to residents.

TABLE 3.3
ECONOMIC ANALYSIS OF RIPARIAN CORRIDOR/IMPROVED CHANNEL ON BLACKJACK CREEK

Discount Rate %	4	7	10
Present Worth Value of Benefits* (Damages Prevented) $ x 10^6	2.6	2.02	1.62
Cost of scheme (capital and annual maintenance costs) $ x 10^6	2.54	2.44	2.38
Benefit/Cost Ratio	1.0	0.8	0.7

Note: * **Section 8.3 of Appendix B** includes a definition of terms used in the economic assessment of flood impacts

3.4 Flood Modification Measures - Construction of Detention Basins

Detention basins provide a temporary storage of floodwaters additional to that contained in the natural floodplain, which can reduce the flood peak in downstream reaches of the creek. "Offline" basins, remote from the streams, with intake and outlet channels to and from the stream, are preferred over embankments constructed across the channel to maintain the continuity of the creek system. However, an offline basin is not feasible on Blackjack Creek due to the limited extent of the floodplain and the nature of existing land use.

The basin should also be located in the middle or lower reaches of the catchment, sufficiently close to the area intended to be protected, that its attenuating effects over flood peaks is not negated by downstream tributary inflows. Typically the basin should command in excess of 60 to 70 percent of the total catchment at the damage centre. An on-line basin could in theory be constructed across the channel and its overbanks downstream of Lincoln Street. The catchment area at this site amounts to 17 km^2, about 70 percent of the 24 km^2 at the Oxley Highway.

Another requirement is that the basin be of sufficient size to store a significant percentage of runoff from the design storm. Basins attenuate the flood peak (i.e. reduce the downstream peak rate of runoff) by temporarily storing the incoming discharge hydrograph and releasing it at a controlled rate.

Flows up to the 100 year ARI would usually be controlled by low level pipes. A portion of the embankment crest in the vicinity of the channel would be depressed and armoured with reno-mattress or equivalent to act as a spillway for the conveyance of higher flows. (Alternatively an armoured by-wash spillway in one of the abutments could be provided.) Small basins are quickly overwhelmed by the incoming flood waters, with the result that the level of stored water quickly rises to the level of the

emergency by-wash spillway. Because the spillway is able to pass a large rate of flow, with little rise in level, the rate of outflow rapidly rises to the rate of inflow, negating the purpose of the basin.

For a basin on Blackjack Creek, the objective would be to reduce the 100 year ARI inflow discharge to an outflow of no more than 20 m^3/s, in order to reduce flows to no greater than the pre-basin 5 year ARI peak, which may be conveyed within the floodplain without surcharging Wandobah Road. Under 100 year ARI conditions, the total volume of runoff entering the basin for storms of duration likely to maximise flows on Blackjack Creek would be around 10^6 m^3, of which 125,000 m^3 is in that part of the hydrograph above the rate of 20 m^3/s and would need to be stored, with the remainder below 20 m^3/s released through the low level outlets. Containment of this volume would require a rectangular storage area of 300 m by 300 m at an average depth of 1.4 m.

The potential basin site downstream of Lincoln Street has not been surveyed. On the basis of available 2 m contour mapping, it appears that a volume of 40,000 m^3 could be achieved by storing water to an average depth of 1 m on the overbank areas. Greater depths would extend outside the available area. Within the channel, the depth of ponding would be around 3 m. The available volume of 40,000 m^3 is less that one third of the required volume.

These values indicate that detention basins would not be a feasible flood management measure for Blackjack Creek and should not be included in the list of management measures for the draft *Floodplain Risk Management Plan*.

3.5 Flood Modification Measures - Levees

3.5.1 General

Levees are an effective means of protecting flood affected properties up to the chosen design flood level. In designing a levee, it is necessary to take account of potential adverse re-direction of flood flows, the requirements for disposal of internal drainage from the protected area and the consequences of overtopping the levee in floods greater than the design event.

Reinforced concrete and concrete block walls are often used in situations where there is insufficient land available for earth banks. Such walls are provided with reinforced concrete footings of sufficient width to withstand overturning during flood events. A recent example of this form of construction is the levee scheme for the town of Lismore which protected the town from a severe flood a short time after its opening.

A major difficulty with urban levee schemes is the provision of facilities for the collection, temporary storage and disposal of stormwater runoff derived from the local sub-catchments within and upstream of the protected area. In some situations, evacuation of local runoff by pumping over the levee has been adopted where there is insufficient area available to store runoff for later disposal by gravity as the flood recedes. In other situations, separate provisions are made for the collection and transfer of stormwater runoff along the protected side of the levee, downstream to a location where the flood gradient in the main stream allows its conveyance back to the main stream by gravity. (This latter method of disposal has been adopted in the Blackjack Creek levee proposal described below).

3.5.2 Potential for Levees along Blackjack Creek

Figure 3.3 shows a proposal for a levee aimed at providing a 100 year ARI level of flood protection.

The levee would commence at Bando Street and continue for 850 m along the western side of Wandobah Road to meet the existing section of levee, which extends over 400 m from George Street to Short Street. The levee would then continue 400 m to a point about 200 m upstream of the Oxley Highway. The purpose of terminating the levee at that location is to allow local stormwater drainage to be discharged by gravity to the creek. Under the concept, runoff from Council's local stormwater system would be collected and conveyed in the channel shown on **Figure 3.3** running northwards between the levee and Wandobah Road. At the proposed discharge point, it appears from existing survey that main stream flood levels have fallen to the level where the stormwater runoff may be safely discharged without backwater levels from the Oxley Highway influencing flooding in the residential area.

Hydraulic modelling showed that 100 year ARI flood levels in Blackjack Creek would be increased by up to 330 mm due to the constricting effects of the levee. For the purposes of this analysis it was assumed that the crest of the levee would be 1 m above the level of the 100 year ARI flood under post-levee conditions. The freeboard is a factor of safety which allows for wave action, uncertainties in the assessment of 100 year ARI flood levels, construction tolerances and potential settlement of the levee.

Survey information along the route of the levee is sparse, with information on natural surface levels being confined to the cross sections of the creek incorporated in the hydraulic model of the floodplain developed for the flood studies (their locations are shown on **Figure 3.3**), as well as Council's 2 m contour data. Based on this information, the height of the levee would range between 900 mm and 2.1 m.

To achieve the design crest level, the section of existing levee would need to be raised by up to 1 m. It has been assumed for costing purposes that the existing levee will be incorporated in the new works. However, this assumption is subject to geotechnical testing at the design stage, as the engineering properties and compaction of the fill material are presently unknown.

3.5.3 Provisions for Discharge of Stormwater

The provision of facilities for the temporary detention and release of runoff from the protected areas whilst creek levels are maintained was an important issue in planning for the levee. During major floods, elevated water levels will be maintained in the creek for a period of up to four hours.

Figure 3.4 shows the stage hydrographs at the outlets of Council's piped stormwater system resulting from the occurrence of a 100 year ARI storm of 180 minutes duration (the critical storm for Blackjack Creek). This diagram also shows discharge hydrographs at the outlets of the stormwater system resulting from the occurrence of a 100 year ARI storm of 60 minutes duration (the critical storm for the local sub-catchments). The stormwater hydrographs have been moved in time to correspond with the peak of the Blackjack Creek flood to demonstrate the time over which high levels are maintained in the creek, relative to the time of high flows in the local sub-catchments.

In the absence of the proposed channel running between the levee and Wandobah Road, these stormwater flows would have to be stored, pending drainage to the creek as floodwaters recede. To prevent back flooding from the creek when water levels are near their peak, the piped drains running under the levee would need to be flap gated. Volumes of around 40,000 m^3 would have to be stored in dedicated storage areas behind the levee. There are no sites capable of being developed to accommodate such a large volume. Absence of a suitable storage site led to the proposal for disposal

of local stormwater runoff via the channel running along the protected side of the levee. Under that proposal the stormwater pipes would discharge directly to the channel, without the need for flap gates.

The ability to achieve the discharge of the local stormwater runoff via the channel and return the flow to Blackjack Creek upstream of the Oxley Highway (as shown on **Figure 3.3**) under gravity conditions would need to be confirmed by additional survey should the levee option proceed further.

3.5.4 Indicative Cost of Levee

The indicative capital cost estimate for the levee is given in **Table 3.4.** The cost contains a larger cost allowance for un-estimated items and contingencies than the riparian corridor/improved channel scheme (35 per cent versus 20 per cent). This is to account for the greater uncertainties associate with the levee scheme regarding the capture and disposal of local stormwater runoff.

TABLE 3.4
INDICATIVE CAPITAL COST OF LEVEE
100 YEAR ARI DESIGN STANDARD

Item	Cost $
Preliminaries (Establishment, Geotechnical Testing, Sediment Control)	15,000
Clear and Grub Site	55,000
Strip and Store Topsoil for later re-use on excavated surfaces	44,000
Excavate 300 m reach to relocate channel and fill and compact existing channel of Blackjack Creek near George Street	31,000
Grass seed invert and batters of re-located channel of Blackjack Creek	37,500
Roll and compact levee foundation	107,000
Supply and compact impervious fill for levee embankment	880,000
Excavate from stockpile and spread topsoil over all excavated surfaces	54,000
Grass seed levee batters	115,000
Excavate for channel to convey stormwater runoff from the urban catchments to the outfall at the intersection of Wandobah Road and View Street	115,000
Grass seed stormwater channel batters	123,000
Survey, investigation and design (10%)	158,000
Un-estimated items and contingencies (35%)	607,000
TOTAL ESTIMATED CAPITAL COSTS	**$2.34M**

Annual maintenance costs amounting to 1.5 percent of the capital cost have been converted to a present worth value and added to the above capital cost to obtain an indicative total cost of the scheme, which has been used in the economic analysis of **Section 3.5.5**.

3.5.5 Economic Assessment of Levee

Table 3.5 provides indicative costs of a levee scheme to mitigate damages. The total cost including capital and annual maintenance costs is about $2.67 Million for the 7 per cent discount rate,

compared with $2.02 Million in terms of flood damages prevented. The benefit/cost ratio of the scheme at the 7 per cent discount rate is about 0.7.

TABLE 3.5
ECONOMIC ANALYSIS OF LEVEE SCHEME ON BLACKJACK CREEK

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Prevented) $ x 10^6	2.6	2.02	1.62
Cost of scheme (capital and annual maintenance costs) $ x 10^6	2.77	2.67	2.61
Benefit/Cost Ratio	0.9	0.7	0.6

3.5.6 Environmental Constraints

By comparison of the data in **Tables 3.3** and **3.5**, the riparian corridor/improved channel is more economically attractive than the flood protection levee and is likely to score considerably higher than the levee scheme on the multi-objective scoring system of **Chapter 4** of the report. The creation of the visually attractive riparian corridor is likely to score highly on both environmental grounds and conforming with Government policies and is also likely to be viewed favourably as meeting community objectives.

On the other hand the levee scheme, although scoring well in terms of meeting flood mitigation objectives may not be viewed favourably by the community because of its visual impact. At present there is a clear visual and physical linkage between the creek and the residential community on the eastern floodplain, as well as for users of the new cycleway running along Wandobah Road. Construction of a levee up to 2 m in height would impact on this linkage.

3.6 Property Modification Measures – Development Controls

3.6.1 Considerations for Setting Flood Planning Level

Selection of the **Flood Planning Level** (*FPL*) for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain management plans. It is based on adoption of the peak level reached by a particular flood plus an appropriate allowance for freeboard. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the risk to life and limb. If the adopted *FPL* is too low, new development in areas above the *FPL* (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high flood planning level will subject land that is rarely flooded to unwarranted controls.

Councils are responsible for determining the appropriate *FPL*'s within their local government area. Whilst the flood used to determine the residential *FPL* is a decision of the Council, the FPM, 2005

highlights that *FPL*'s for typical residential development would generally be based around the 100 year ARI flood, plus an appropriate freeboard (typically 500 mm).

3.6.2 Current Government Policy

The circular issued by the Department of Planning on 31 January 2007 contained a package of changes clarifying flood related development controls to be applied on land in low flood risk areas (land above the 1 in 100 year flood). The package included an amendment to the Environmental Planning and Assessment Regulation 2000 in relation to the questions about flooding to be answered in Section 149 planning certificates, a revised ministerial direction (Direction 15) regarding flood prone land (issued under Section 117 of the EP&A Act, 1979) and a new Guideline concerning flood-related development controls in low flood risk areas.

The Circular advised that Councils will need to follow both the Floodplain Development Manual, 2005 as well as the Guideline to gain the legal protection given by Section 733 of the Local Government Act.

The Department of Planning Guideline confirmed that **unless exceptional circumstances applied, councils should adopt the 100 year ARI flood (1 in 100 year flood) with appropriate freeboard as the *FPL* for residential development**. In proposing a case for exceptional circumstances, a Council would need to demonstrate that a different *FPL* was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. Unless there were exceptional circumstances, Council should not impose flood-related development controls on residential development on land with a low probability of flooding, that is land above the residential *FPL*.

Nevertheless, the safety of people and associated emergency response management needs to be considered in low flood risk areas, which may result in:

- Restrictions on types of development which are particularly vulnerable to emergency response, for example, developments for aged care.
- Restrictions on critical emergency response and recovery facilities and infrastructure. These aim to ensure that these facilities and the infrastructure can fulfil their emergency response and recovery functions during and after a flood event. Examples include evacuation centres and routes, hospitals and major utility facilities. There are currently no critical developments of this nature in the Blackjack Creek floodplain.

3.6.3 Proposed Flood Planning Levels

Consideration of the data supports retaining the 100 year ARI flood plus a freeboard allowance of 500 mm for floor levels of residential development, along with a graded set of controls depending on the location of the development within the area flooded by that event.

3.6.4 Amendments to Council's Flood Policy

Features of the existing *Flood Policy* for Gunnedah were described in **Chapter 2** of the study and proposed amendments outlined (ref. **Sections 2.8.5** and **2.8.6**). As noted, Council's existing policy is based on flooding from the Namoi River and does not specifically relate to the Blackjack Creek floodplain. However, it is considered that the existing policy (with the minor amendments outlined in **Section 2.8.6**) could be adopted to control future development on Blackjack Creek.

It was proposed that the flood prone land in Blackjack Creek be divided into four planning zones:

- The ***Floodway*** is a narrow strip of land running along the centreline of the creek and extends eastwards to Wandobah Road and is the most flood affected land.The Policy considers that *new residential development* is an unsuitable use for land which is located in the ***Floodway***.
- The ***Intermediate Floodplain*** comprises areas to the east of Wandobah Road, which may convey flows during major floods. There, flood related controls relate to setting minimum floor levels of new properties above the ***Flood Planning Level***. The Policy recognises that because overland flow velocities may be significant, new development in this area could result in an adverse re-direction of flows towards existing developments in the floodplain and that special precautions need to be taken to prevent this occurrence. Accordingly, the Policy requires development to be designed to minimise obstructions to the passage of floodwaters caused by site filling and fences, as well as providing minimum floor levels above the peak 100 year ARI flood level plus 500 mm of freeboard. These requirements will ensure that floor levels are above the level of major flooding and reduce the potential for flood damages both to the development itself as well as surrounding properties.
- In the ***Flood Fringe***, the Policy nominates the peak 100 year ARI flood level plus 500 mm freeboard as the ***Flood Planning Level*** for *new residential development*. The policy considers that flow velocities are not likely to be significant in the ***Flood Fringe***.
- There would be no flood related development controls over residential development in the ***Outer Floodplain***, apart from the minimum floor level requirement of peak 100 year ARI flood level plus 500 mm of freeboard. This requirement will ensure that floor levels of new developments located on ground slightly outside the extent of the 100 year ARI flood are no lower than equivalent properties within that extent.

3.7 Property Modification Measures - Voluntary Purchase of Residential Properties

Removal of housing from high hazard floodway areas in the floodplain is generally accepted as a cost effective means of correcting previous decisions to build in such areas. The voluntary purchase of residential property in hazardous areas has been part of subsidised floodplain management programs in NSW for over 20 years. After purchase, land is subsequently cleared and the site redeveloped and rezoned for public open space or some other flood compatible use. A further criterion applied by State Government agencies in assessing eligibility for funding is that the property must be in a high hazard area such as floodway, that is, in the path of flowing floodwaters where the depth and velocity at the peak of the flood are such that life could be threatened, damage of property is likely and evacuation difficult.

Under a voluntary purchase (VP) scheme the owner is notified that the body controlling the scheme, Council in the case of Blackjack Creek, is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site**.**

Hydraulic calculations described in **Chapter 2** showed that strictly speaking, none of the residences flooded on the eastern floodplain were located in high hazard areas. Flow velocities are low and the principal effect of flooding in most properties would be a relatively short duration of shallow, above-floor inundation.

Table 3.6 shows locations of the maximum depths of inundation for the 10 properties subject to the greatest depths of inundation at the 20 year and 100 year ARI flood magnitudes. For example, 5 of the "top ten" properties are located in the King Street area and the maximum depth of above-floor inundation in those properties is 0.88 m for the 100 year ARI flood and 0.71 m for the 20 year ARI event. For the purposes of illustration, an economic analysis was carried out for a VP scheme which would involve the purchase of the two properties with the greatest depth of flooding at the 100 year ARI (0.88 m and 0.65m).

Table 3.7 shows the results of the economic analysis. The analysis has been carried out for the three discount rates nominated by NSW Treasury Guidelines for the economic analysis of public works. The benefits of the scheme comprise the present worth value of the flood damages for the residential two properties which would be saved by their purchase. For the analysis the costs were based on an average purchase cost of $300,000 per property, typical of recent sale prices in the area.

TABLE 3.6
DETAILS OF TEN RESIDENCES SUBJECT TO
DEEPEST ABOVE-FLOOR INUNDATION

Location	Flooded by 100 Year ARI Flood		Flooded by 20 Year ARI Flood	
	No. of Residences in Sample	Max Depth of Inundation – m	No of Residences in Sample	Max Depth of Inundation – m
King Street Area	5	0.88	5	0.71
Schwager Street Area	2	0.65	2	0.18
Short Street Area	2	0.40	2	0.16
View Street Area	1	0.31	1	0.10
Total	**10**	**0.88**	**10**	**0.71**

TABLE 3.7
ECONOMIC ANALYSIS OF VOLUNTARY
PURCHASE SCHEME FOR TWO DEEPEST FLOODED PROPERTIES

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Prevented) $ x 10^6	0.13	0.10	0.08
Cost of Scheme $ x 10^6	0.60	0.60	0.60
Benefit/Cost Ratio	0.22	0.17	0.14

It is clear from the above analysis that a voluntary purchase scheme would not be justified on economic grounds and was not favoured by the community in their responses to the Questionnaire.

A VP scheme is, however, sometimes implemented to clear properties located in high hazard areas on social grounds even though the scheme is not economically feasible. Although the area is subject to "flash flooding" with little warning time, flooding in the street system is relatively shallow, of short duration and there is ready access eastwards to high ground. Accordingly, it is considered that a voluntary purchase scheme would not be justified on social grounds.

3.8 Property Modification Measures - Raising Floor Levels of Residential Properties

This term refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house by a convenient amount so that the floor level is at or above the *FPL*. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses. Most of the costs associated with this measure relate to the disconnection and reconnection of services. Accordingly, houses may be raised a considerable elevation without incurring large incremental costs.

The State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. In accepting schemes for eligibility, the Government has laid down the following conditions:

- House raising should be part of an adopted Floodplain Management Plan.
- The scheme should be administered by the local authority.

The Government also requires that Councils carry out ongoing monitoring in areas where subsidised voluntary house raising has occurred to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level. In addition, it is expected that Councils will provide documentation during the conveyancing process so that subsequent owners are made aware of restrictions on development below the design floor level.

Council's principal role in subsidised voluntary house raising would be to:

- Define a habitable floor level, which it will have already done in exercising controls over new house building in the area.
- Guarantee a payment to the builder after satisfactory completion of the agreed work.
- Monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

The current cost to raise a medium sized (150 square metres) house is between $60,000 and $75,000 based on recent experience in other centres. For the purposes of the economic analysis, a cost of $70,000 was adopted.

Table 3.8 is an economic analysis of a house raising strategy of the same ten properties examined in the VP analysis of **Table 3.6** and for the three discount rates, assuming that all of the properties could

be raised. The benefits of the scheme comprise the present worth value of the flood damages for the residential properties which would be saved by their raising. If the houses were raised to at least the 100 year ARI flood level plus an appropriate freeboard then the scheme's benefits would comprise the damages up to that flood.

TABLE 3.8
ECONOMIC ANALYSIS OF RAISING
FLOORS OF TEN RESIDENCES SUBJECT TO
DEEPEST ABOVE-FLOOR INUNDATION

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Saved) \$ x 10^6	0.55	0.42	0.34
Cost of Scheme \$ x 10^6	0.7	0.7	0.7
Benefit/Cost Ratio	0.8	0.6	0.5

This strategy is not economically feasible for the study area. The community were evenly balanced in their responses to the Questionnaire. Site inspection showed that some of the properties were of brick construction and therefore would be technically difficult to raise. As mentioned, there is ready access to high ground for all of these properties. Accordingly, it is considered that a scheme for raising flood prone houses could not be justified on social grounds and has not been considered further.

3.9 Response Modification Measures - Flood Forecasting, Warning and Evacuation Plans

3.9.1 Flash Flood Warning Systems

Flood forecasting and warning can be an effective flood management measure if there is sufficient warning time for the community to react to the warning. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and an evacuation plan.

Flood response to rainfall on the Blackjack Creek catchments is relatively short and is expected to be between around three to four hours (i.e. from the commencement of heavy rainfall to the occurrence of the flood peak in the lower reaches of the creek near the Oxley Highway – ref. **Figure 2.2**).

A workshop was sponsored by Bureau of Meteorology in 2007 to develop guidelines for the NSW Flood Warning Consultative Committee to co-ordinate funding proposals for local flash flood warning systems. Three levels of local flash flood warning system were identified:

- **General System** – relies on existing warning services provided by the Bureau of Meteorology for severe weather and thunderstorms as well as Flood Watches. These services are typically issued on a regional basis, or for a larger catchment than Blackjack

Creek. These warnings can be augmented by real time information from local weather radars, automatic weather stations and existing rainfall and river gauges. They do not involve additional rainfall or river gauge instrumentation in the catchment. **Indicative cost:** Initial cost zero to $20,000 and annual costs of $1,000 to $7,000 for a public awareness program.

- **Intermediate System** – General system plus additional rain and river gauges within the targeted flash flood catchment to help local emergency personnel to assist the community through improved evaluation and management of the flash flood threat. **Indicative cost:** Initial cost **$**60,000 and annual costs of $10,000 to $15,000 for a public awareness program and maintenance of instrumentation.
- **Total Warning System** – Intermediate system plus a targeted warning dissemination system to people located on the high flood hazard sites where evacuation may be necessary. **Indicative cost:** Initial cost $100,000 to $300,000 and annual costs of $10,000 to $15,000 for a public awareness program and maintenance of instrumentation.

While all systems need to be underpinned by an appropriate public flood awareness program, the **Total Warning System** would require a more comprehensive and recurrent public flood awareness campaign.

Provisionally, the **Total Warning System** is recommended for further consideration in the *FRMP* for Blackjack Creek. It would be based on the "READY", "SET", "GO" warning phases as follows:

- READY – flooding is possible in a general area; monitoring of weather is required.
- SET – flooding is more likely in a specific area; prepare to act.
- GO – flooding is very likely in a specific area; Action required.

The advantages of the **Total Warning System** over the two lesser systems are:

- Enhanced reduction in risk to life and property from flash flooding through precautionary actions triggered by general warnings, as per the **General System** (i.e. READY and SET phases), and targeted Bureau of Meteorology Flash Flood Warnings based on the predicted exceedence of flash flood thresholds (GO phase), being directly communicated to the affected community.
- Reduction (compared with the **Intermediate System**) in risk to life and property from flash flooding by better local emergency response and management, through the Bureau providing forecasts for the exceedence of flood thresholds for the area.

The six components of the **Total Warning System** are:

1. **Predictions**
    - Bureau of Meteorology warnings and information from radar, AWS and rain and river gauges as per the **Intermediate System** used to trigger "READY" and "SET" phases.
    - Targeted Flash Flood Warnings issued by the Bureau of Meteorology for the exceedence of Flash Flood Thresholds based upon information from the *FRMS* for the area to trigger the "GO" phase. Depending on the information from flood modelling, predictions may be issued for flood/no flood scenarios or for levels of flooding resulting from floods of various probabilities of occurrence.

2. Interpretation

- Areas likely to be flooded determined from **flood maps**, from the flood modelling results or studies for the area, and from SES flood intelligence.

3. Warning message Construction

- Pre-determined flash flood warning messages for the specific areas.

4. Communication

- Warnings broadcast by media and available on the BOM website.
- Warnings directly communicated to the affected area either automatically or manually, depending on the size of the catchment, population size and available SES resources.

5. Response

- Pro-active community and SES response underpinned by local recurrent public flood awareness/education program.

6. Review

- Performance of the system after each major flood.
- Regular review of the readiness and maintenance of system components such as gauges, communications, public education and planning.

Funding to establish local flash flood warning systems has traditionally been made available on the basis of no Council contribution to the initial capital cost in recognition of the high maintenance costs which Council would have to meet. The costs of maintaining the system would include such items as rain and river gauges, warning communication systems and ongoing public awareness/education programs. The maintenance obligations would need to be identified and included in any initial funding grant. Upon installation of the local flash flood warning system, the SES Local Flood Plan for the area could be used to document the operation and maintenance specifications of the system, including the public education/awareness components.

3.9.2 Flash Flood Warning System – Discussion

Assuming an initial capital cost of $200,000 and annual cost of $10,000 for maintenance, the total cost of the Total Warning System at the 7 per cent discount rate would be about $358,000 over an economic life of 20 years. Assuming the system was effective in mitigating damages to contents up to the 100 year ARI flood, it would need to reduce damages to contents by about 50 per cent to be economically feasible. This would probably not be achievable and therefore the system would have to be justified on social and other non-economic grounds.

Further, if either of the structural mitigation schemes (riparian corridor or levee) were constructed in a reasonable timeframe then it may be difficult to justify implementation of the system (even though a flash flood warning scheme was strongly favoured by the community), as those schemes would provide protection to the 100 year ARI level of flooding. The system would then have to be justified on the warning it provides against flooding due to surcharges of the local stormwater system.

3.10 Response Modification Measures - Public Awareness Programs

3.10.1 General Comments

Community awareness and appreciation of the existing flood hazards in the floodplain would promote proper land use and development in flood affected areas. A well informed community would be more receptive to requirements for flood proofing of buildings and general building and development controls imposed by Council. One aspect of a community's preparedness for flooding is the "flood awareness" of individuals. This includes awareness of the flood threat in their area and how to protect themselves against it. It is fair to assume that the level of awareness drops as individuals' memories of previous experience dim with time.

Means by which community awareness of flood risks can be maintained or may be increased include:

1. Sending out regular information with rates notices. The information contained in this present study could be edited and used by Council and SES to prepare a *Flood Information Brochure* for Blackjack Creek.
2. Displays at Council offices using the information contained in the present study and photographs of historic flooding in the area.
3. Talks by SES officers with participation by Council and longstanding residents with first hand experience of flooding in the area.

3.10.2 Flood Information Brochure

The *Flood Information Brochure* (also known as a "FloodSafe" brochure) which could also form a component of the education process associated with the Flash Flood Warning system should contain information on:

- What steps for residents to take in advance to protect themselves from flooding.
- Developing procedures for lifting contents above flood level and evacuating property.
- An Evacuation Plan for the area showing the best routes for egress from the floodplain.
- Evacuation routes would have to be developed in the light of further analyses by Council to assess streets which are vulnerable to surcharges from the local stormwater system. Council could undertake additional analyses using their recently developed DRAIND model of the system to provide this information.

The benefits of a regular flood-preparedness campaign would extend to more than just reducing monetary losses. The campaign would also have social benefits by improving people's feeling of control, since they would have a better idea of how to respond to a flood emergency. Given the recent history of flooding in the area and the Community's high state of flood awareness evidenced in responses to the Questionnaire, it would not appear difficult to generate the interest and co-operation required.

3.11 Summary

This Chapter has reviewed a number of potential floodplain management measures. Preliminary analysis of the flood modification measures (i.e. involving the construction of engineering works) has

been undertaken and indicative cost estimates prepared on the basis of available survey data. The findings are summarised in **Table 3.9** and outlined below.

- Improvements to increase the conveyance capacity of the creek associated with the implementation of a riparian corridor are supported by the Community and are worth considering further by the Committee for inclusion in the draft *FRMP*.

- The construction of a flood protection levee along the right bank of the creek could be considered as an alternative to the riparian corridor in mitigating flooding. The principal constraints of a levee scheme, however, are the adverse environmental impact of the levee on residents the eastern side of the creek and the difficulties of disposing of local stormwater runoff from the protected areas. Further investigation with the benefit of additional survey information would be required to confirm its feasibility.

- Planning controls separately or in combination with the above measures are an essential component of the Floodplain Risk Management Plan. Modifications to Council's existing Gunnedah wide Flood Policy are suggested.

- Response modification measures which are supported comprise incorporation of flood improved flood awareness via the preparation of a Flood Information Brochure and incorporation of flood data included in this *FRMS* in SES's Local Flood Plan.

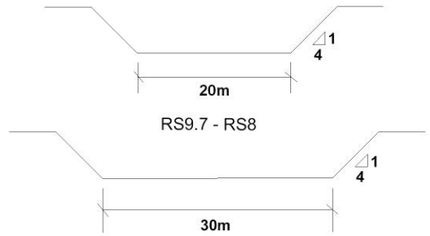
- Further consideration of a *Flash Flood Warning System* for Blackjack Creek catchment may be justified if the riparian corridor scheme or flood protection levee alternative does not proceed in a reasonable timeframe.

TABLE 3.9
REVIEW OF POTENTIAL FLOOD MANAGEMENT MEASURES

Scheme	Comments
Riparian Corridor /Channel Improvement Scheme	This measure would be supported by DECCW and Namoi CMA. It would be a dual purpose project providing environmental and flood mitigation benefits. A riparian corridor on Blackjack Creek is considered worthy of further consideration for inclusion in the *FRMP*. A feasibility study is required to develop concept designs and prepare a case for Government funding.
Construct Levee	It is technically feasible to construct a levee to the 100 year ARI level plus freeboard. However, an excavated channel running along the "protected" side of the levee would be required to capture and dispose of runoff from the local stormwater system. This scheme is less attractive economically than the riparian corridor and will impact on the visual and physical connection between the creek and eastern floodplain. It is therefore environmentally less attractive and may not have the support of the community. It should only be included in the *FRMP* in the event that the riparian corridor/channel improvement does not proceed.
Construct Detention Basins	There are no natural storage areas of sufficient size in the middle reaches of Blackjack Creek to mitigate downstream flood peaks. Construction of an effective detention basin would require considerable land acquisition and excavation. Detention basins are not considered to be a feasible flood management measure for inclusion in the *FRMP*.
Voluntary Purchase of Residential Property	This measure is sometimes employed to remove residential development from high risk areas of the floodplain. Implementation of a voluntary purchase scheme for the Blackjack Creek catchment is not economically justified. In view of the relatively shallow and short duration of flooding which would be experienced in these residences and the ready access to high ground from the flood affected areas, the scheme could not be justified on social grounds.
House Raising	This measure is sometimes employed to raise residential development in medium and low hazard areas of the floodplain. Implementation of a house raising scheme for Blackjack Creek is not economically warranted. In view of the relatively shallow and short duration of flooding which would be experienced in these residences, the scheme could not be justified on social grounds.
Planning Controls (Flood Policy)	This is a low cost and essential component of the Floodplain Risk Management Plan and will over time reduce damages. Council's existing Flood Policy recommends a graded set of controls for development, which depends on the nature of the development and its location within the floodplain. The Policy could be adopted for Blackjack Creek with some minor amendments and could be used for future development pending construction of the structural works outlined above.
Flood Warning and Forecasting	It is not technically feasible to provide extended warning times with a conventional flood warning system. A Flash Flood Warning System along the lines of the system outlined in **Section 3.9** would reduce the present day flood risk. However, if the riparian corridor scheme proceeds, the flood risk would be reduced and a formal Flash Flood Warning system may not be required. SES and other emergency management authorities should use the flood information contained in this *FRMS* to update their procedures for flood response and evacuation, pending construction of the improved channel/riparian corridor.
Flood Awareness	Continuation of Council's policy of notifying flood affectation on S149 Certificates for properties impacted by floods up to 100 year ARI is supported. The affectation notices could be removed with the implementation of the riparian corridor or levee scheme. Flood awareness would be increased by the Council and SES collaborating to prepare a FloodSafe Brochure for Blackjack Creek.

TYPICAL CROSS SECTIONS

SEE NOTE 2



SEE NOTE 1

RS 1.1

RS 1.9

RS 2.1

RS 3

RS 4

RS 5

RS 5.5

RS 6

RS 7

RS 8

RS 8.5

RS 9

RS 9.7

RS 10

SEE NOTE 3

VIEW ST

WANDOBAH RD

SHORT ST

KILCOY ST

HIGH ST

KING ST

DOUGLAS ST

JAEGER AV

HEILER ST

GEORGE ST

SCHWAGER ST

HOPEDALE AV

PIKE ST

HASSAW PL

JARMAIN CL

VILLA ST

NEWELL AV

HERBERT ST

O'KEEFFE PL

McDONAGH PL

HOPEDALE AV

BANDO ST

LINCOLN ST

McAndrew Park

OXLEY HWY

LLOYD RD

BORTHISTLE RD

ALFORD RD

O'NEIL RD

TALBOT RD

MARTIN RD

BENNETT RD

BEDFORD RD

HOWES RD

NOTES

1. IMPROVED CHANNEL TO EXTEND TO OXLEY HIGHWAY CROSSING.

2. BATTER IS AN AVERAGE VALUE AND VARIES OVER EXTENT OF CHANNEL TO MIMIC NATURAL STREAMS.

3. MOUNDING OF NATURAL SURFACE TO CAPTURE OVERLAND FLOWS.

N

100 0 100 200 300m

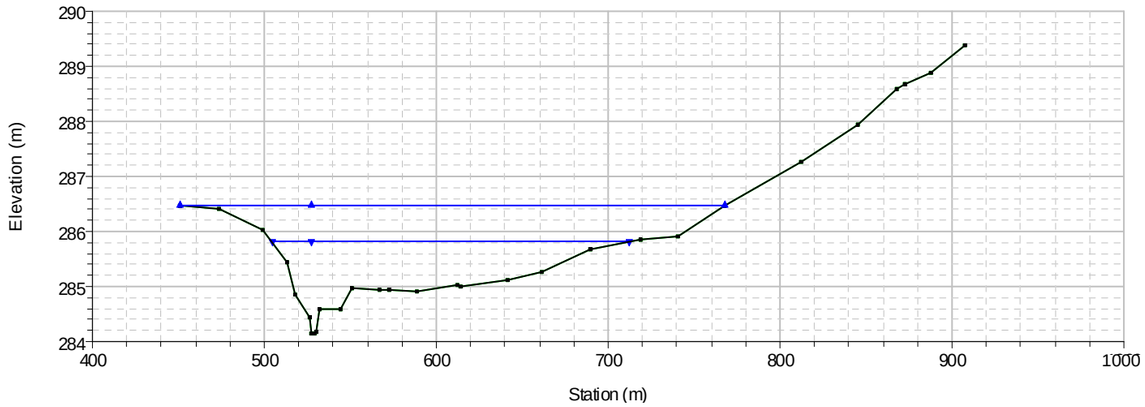
Scale: 1:6,000

LEGEND

- 100 YEAR ARI FLOOD EXTENT (PRE-IMPROVED CHANNEL)
- APPROX. EXTENT OF IMPROVED CHANNEL
- RS 9 — Cross Section Location and HEC-RAS Model River Station Number
- STORMWATER PIT AND PIPE NETWORK

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY
Figure 3.1
RIPARIAN CORRIDOR/
IMPROVED CHANNEL

RS = 10



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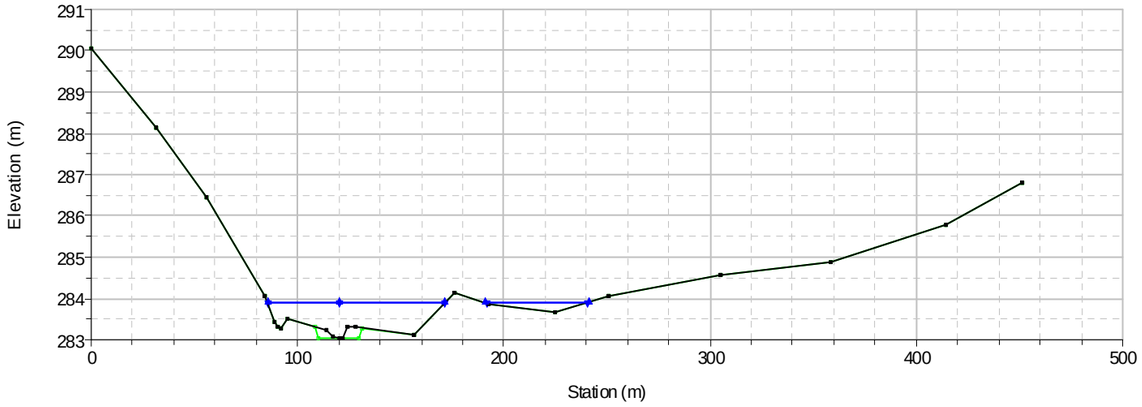

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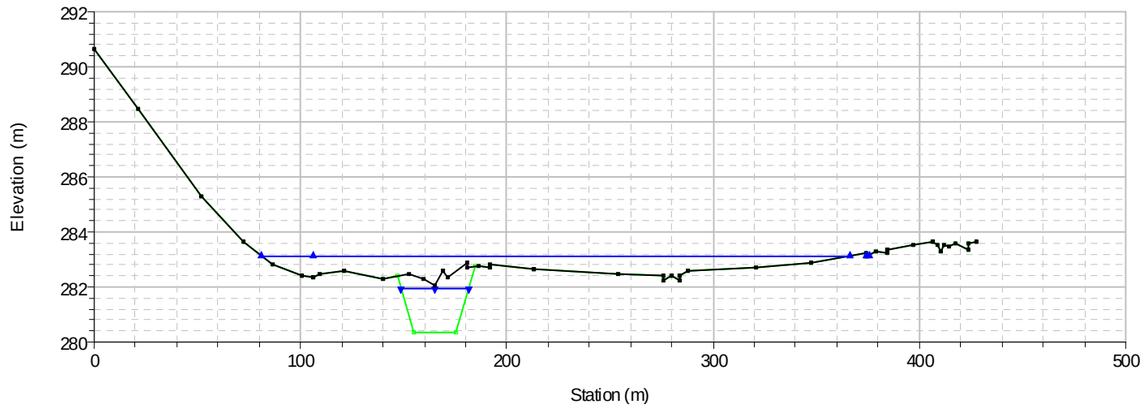

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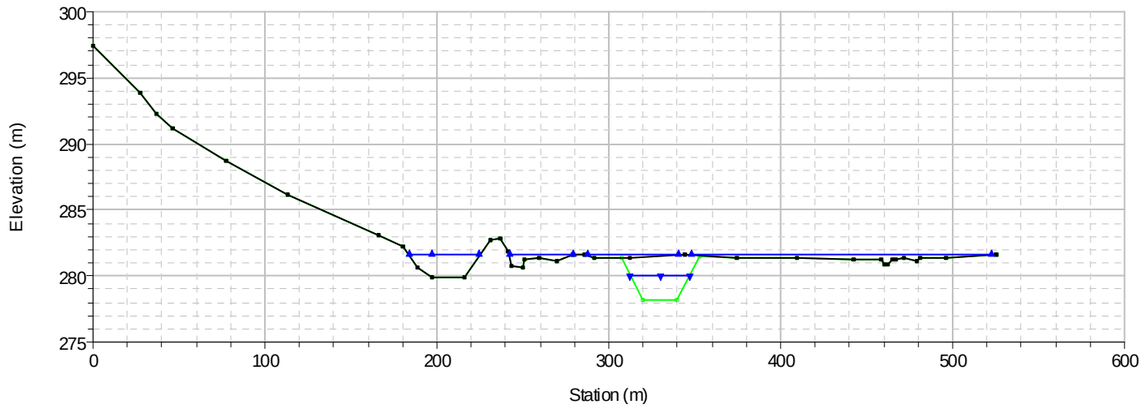

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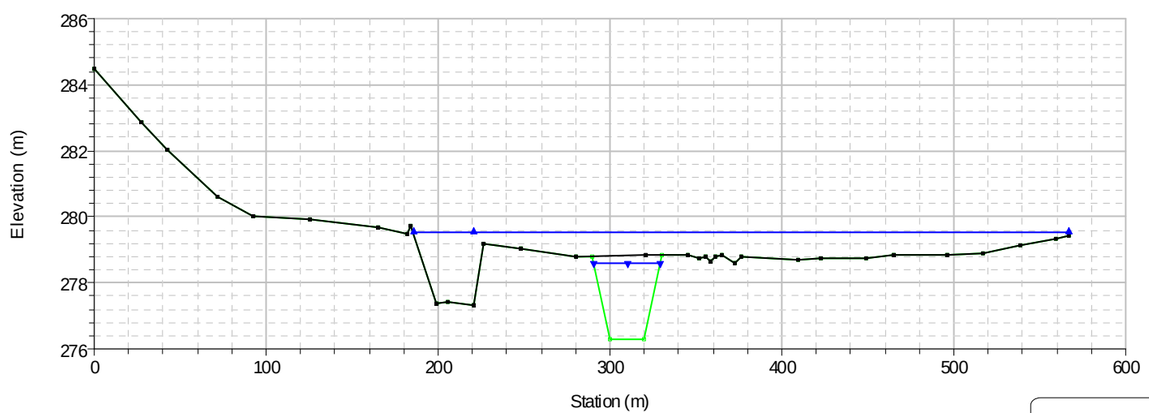

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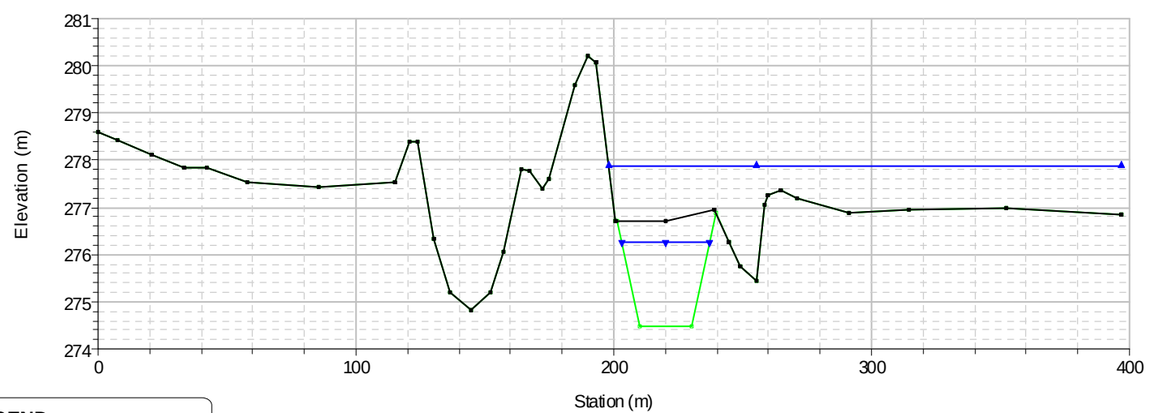

LEGEND

- WS - PRESENT DAY
- WS - IMPROVED CHANNEL
- NATURAL SURFACE
- IMPROVED CHANNEL

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 3.2 - Sheet 1 of 2

RIPARIAN CORRIDOR/ IMPROVED CHANNEL CROSS SECTIONS

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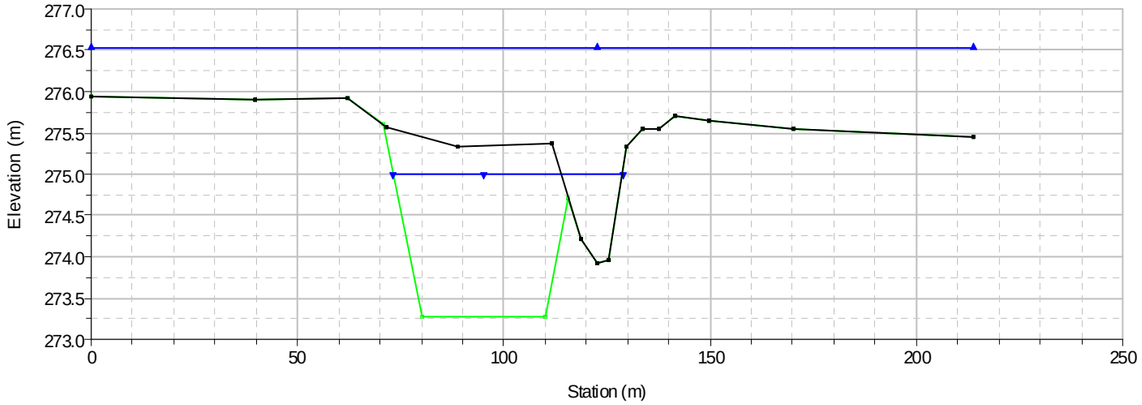

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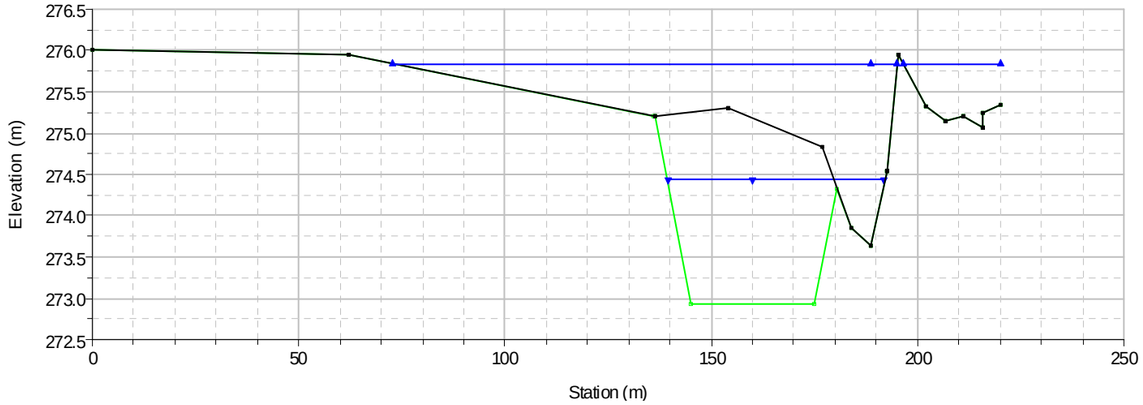

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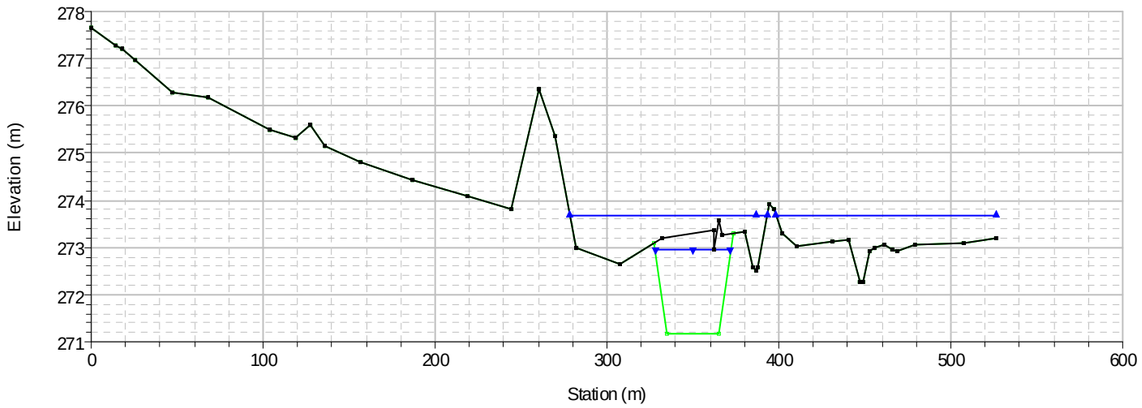

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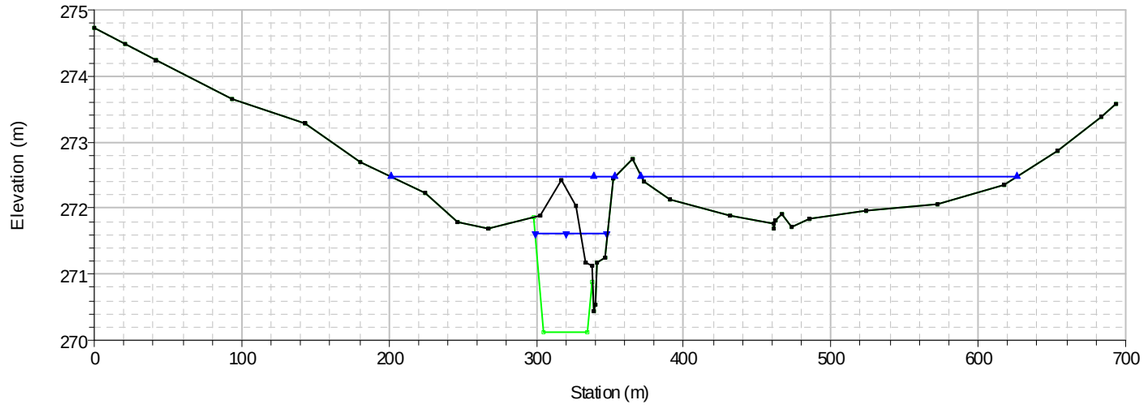

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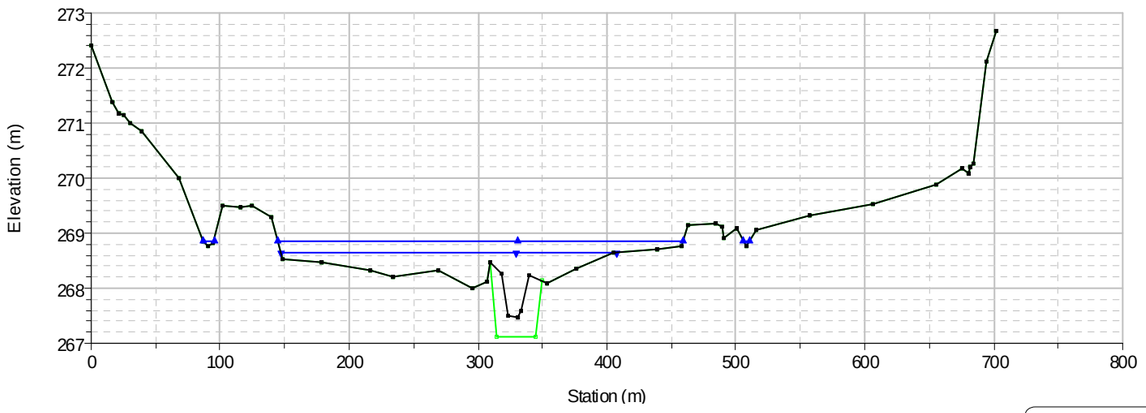

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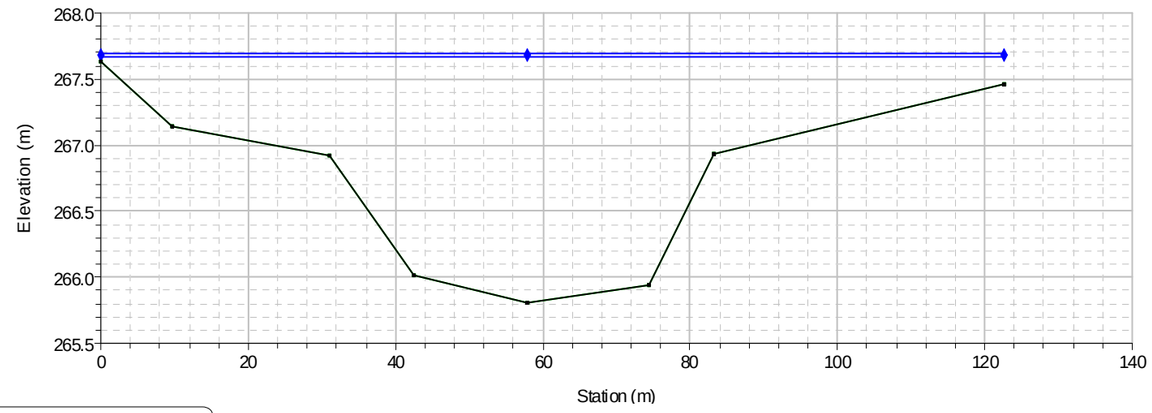


LEGEND

- WS - PRESENT DAY
- WS - IMPROVED CHANNEL
- NATURAL SURFACE
- IMPROVED CHANNEL

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 3.2 - Sheet 2 of 2

RIPARIAN CORRIDOR/ IMPROVED CHANNEL CROSS SECTIONS

LOCAL CATCHMENT
FLOWS DISCHARGE TO
BLACKJACK CREEK

SHORT STREET
OUTLET

KILCOY STREET
OUTLET

GEORGE STREET
OUTLET

HIGH STREET
OUTLET

WANDOBAH ROAD
OUTLET

BLACKJACK CREEK

McAndrew
Park

SOUTH ST
VIEW ST
WANDOBAH RD
SHORT ST
KILCOY ST
HIGH ST
KING ST
DOUGLAS ST
JAEGER AV
STEWART ST
HEILER ST
GEORGE ST
SCHWAGER ST
HOPEDALE AV
MCANDREW ST
PIKE ST
HASSAN PL
JARMAIN CL
NEWELL AV
HERBERT ST
O'KEEFE PL
MCDONAGH
BANDO ST
LLOYD RD
BORTHISTLE RD
OXLEY HWY
ALFORD RD
MARTIN RD
O'NEIL RD
BENNETT RD

RS 1.9
RS 2.1
RS 3
RS 4
RS 5
RS 5.5
RS 6
RS 7
RS 8
RS 8.5
RS 9
RS 9.7

LEGEND

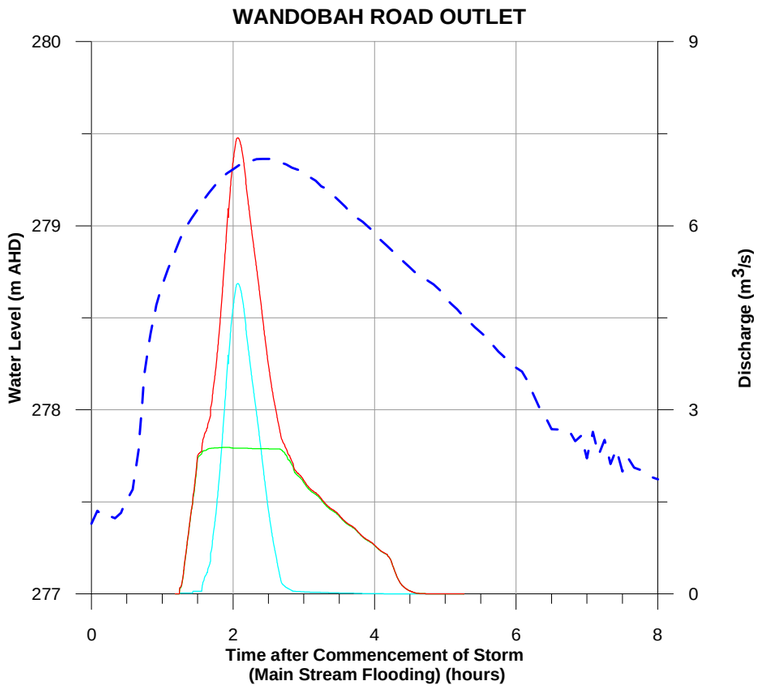
- INDICATIVE 100 YEAR ARI FLOOD EXTENT (PRE-LEVEE)
- LEVEE
- PIPED LOCAL STORMWATER SYSTEM
- RS 9 — Cross Section Location and HEC-RAS Model River Station Number
- STORMWATER CHANNEL

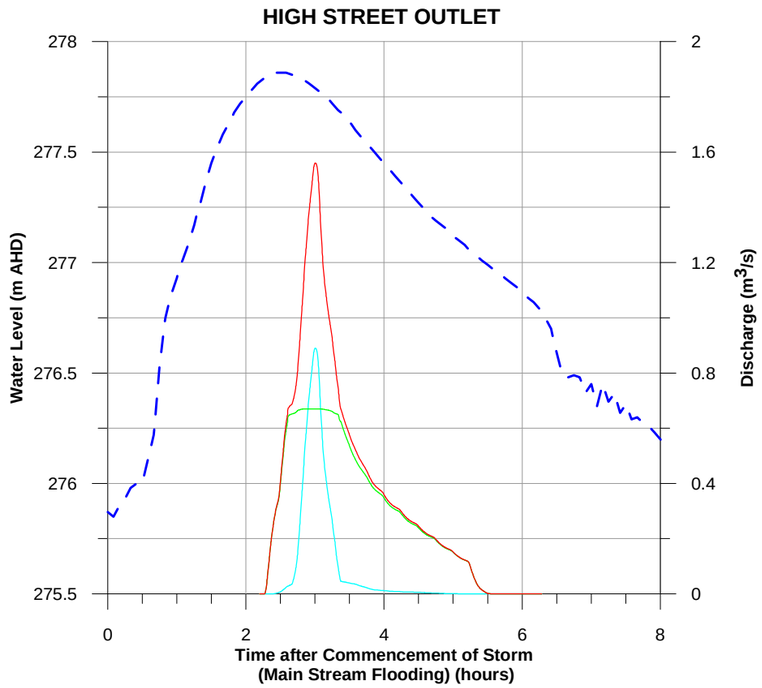
N

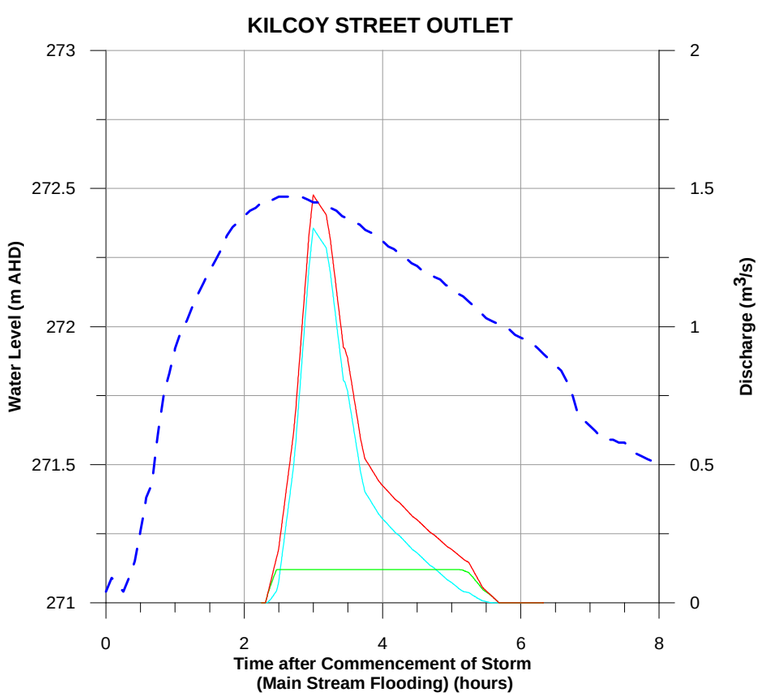
100 0 100 200 300m

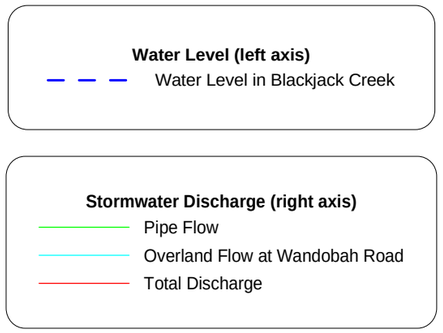
Scale: 1:5,000

BLACKJACK CREEK
FLOODPLAIN RISK MANAGEMENT STUDY
Figure 3.3
FLOOD PROTECTION LEVEE
100 YEAR ARI









BLACKJACK CREEK
FLOOD PLAIN RISK MANAGEMENT STUDY

Figure 3.4

DISCHARGE HYDROGRAPHS AT LOCAL STORMWATER OUTLETS TO BLACKJACK CREEK
100 YEAR STORM

4 SELECTION OF FLOODPLAIN MANAGEMENT MEASURES

4.1 Background

The *Floodplain Development Manual, 2005* requires a Council to develop a *Floodplain Risk Management Plan* based on balancing the merits of social, economic and environmental considerations which are relevant to the community. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works and measures that should be included in the overall *Plan*.

The community will have different priorities and, therefore, each needs to establish its own set of considerations used to assess the merits of different options. The considerations adopted by a community must, however, recognise the State Government's requirements for floodplain management as set out in the *Floodplain Development Manual, 2005* and other relevant policies. A further consideration is that some elements of the *Plan* may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account.

Typically, State and Federal Government funding is given on the basis of merit, as judged by a range of criteria:

- The magnitude of damage to property caused by flooding and the effectiveness of the option in mitigating damage and reducing the flood risk to the community.
- Community involvement in *Plan* preparation and acceptance of the option.
- The technical feasibility of the option (relevant to structural works).
- Conformance of the option with Council's planning objectives.
- Impacts of the option on the environment.
- The economic justification, as measured by the benefit/cost ratio of the option.
- The financial feasibility as gauged by Council's ability to meet its commitment to fund its part of the cost.
- The performance of the option in the event of a flood greater than the design event.
- Conformance of the option with Government Policies (eg *FDM, 2005*, Rivers and Estuaries Policy and Catchment Management objectives).

4.2 Ranking of Options

A suggested approach to assessing the merits of various options is to use a subjective scoring system. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in the plan and what should be left out. Rather, it provides a method by which the Council can re-examine its options and if necessary, debate the relative scoring given to aspects of the plan.

Each option is given a score according to how well the option meets the criteria identified in **Section 4.1** above. In order to keep the scoring simple the following system is proposed:

+2 Option rates very highly

+1 Option rates well

0 Option is neutral

-1 Option rates poorly

-2 Option rates very poorly

The scores are added to get a total for each option.

Based on considerations outlined in this chapter, **Table 4.1** presents a scoring matrix for the options reviewed in **Chapter 3**. This scoring has been used as the basis for prioritising the components of the draft *Floodplain Risk Management Plan*. ***The proposed scoring and weighting shown in Table 4.1 was reviewed by the Committee as part of the process of preparing the draft Plan****.*

4.3 Summary

Table 4.1 indicates that there are good reasons to consider including the following elements into the draft *Floodplain Risk Management Plan*:

- Planning Controls via Council's existing Flood Policy for Gunnedah.
- Incorporation of the Catchment Specific information on flooding impacts contained in this Study in SES Emergency Management Procedures and Flood Awareness documentation for the study area.
- Riparian Corridor/Channel Improvement scheme on Blackjack Creek to provide flood mitigation and environmental benefits.
- Flood Protection Levee to protect residential area east of Wandobah Road (as an alternative mitigation measure to the above scheme).
- Flash Flood Warning System (in the event that the two structural mitigation measures do not proceed).

Property modification measures such as voluntary purchase of residential property or house raising schemes are not considered justified.

TABLE 4.1
BLACKJACK CREEK
ASSESSMENT OF FLOODPLAIN MANAGEMENT OPTIONS

Option	Impact on Flooding/ Reduction in Flood Risk	Community Acceptance	Technical Feasibility	Planning Objectives	Environ. Impacts	Economic Justification	Financial Feasibility	Extreme Flood	Government Policies and TCM Objectives	Score
Flood Modification										
Channel Improvement/Riparian Corridor	+2	+2	+1	+2	+2	0	-1	0	+2	+10
Flood protection Levee along east bank	+2	+1	0	0	-1	0	-1	0	+1	+2
Property Modification										
Flood Related Controls over future development (via Council Flood Policy)	+2	+2	0	+2	0	+2	0	0	+2	+10
House Raising in Low Hazard Areas	0	+1	0	+1	0	-2	-2	0	+1	-1
Voluntary Purchase of Residential Property	0	0	0	+1	0	-2	-2	+1	+1	-1
Response Modification										
Improvements in Flood Warning and Response	+2	+2	0	+1	0	+1	+1	+1	+1	+9
Community Education and Flood Awareness	+1	+2	0	+1	0	+1	0	+1	+2	+8
Certificate of Flood Affectation of property	+2	+2	0	+2	0	+1	0	+1	+2	+10

5 DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

5.1 The Floodplain Risk Management Process

A draft *Floodplain Risk Management Plan* (*FRMP*) has been prepared for the Blackjack Creek catchment as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain. The *FRMP* has been prepared as part of the Floodplain Risk Management Process in accordance with NSW Government's Flood Prone Land Policy.

The first steps in the process of preparing the *FRMP* were the collection of Flood Data and the review of the Flood Study for Blackjack Creek prepared in 2005. That Flood Study was the formal starting process of defining management measures for flood liable land and represented a detailed technical investigation of flood behaviour in the catchment.

5.2 Purpose of the Plan

The objectives of the *Floodplain Risk Management Study and Plan* were to assess the impacts of flooding, review policies and options for management of flood affected land and to develop an *FRMP* which:

- Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding and establishes a program and funding mechanism for the *FRMP*.
- Proposes amendments to Council's existing policies to ensure that the future development of flood affected land on Blackjack Creek is undertaken so as to be compatible with the flood hazard and risk.
- Ensures the *FRMP* is consistent with local emergency management planning.
- Ensures that the *FRMP* has the support of the community.

5.3 The Study Area

This *FRMP* deals with the floodplain of the Blackjack Creek which has a total catchment area of 24 km^2 at its confluence with the Namoi River. For the purposes of this Plan the study focusses of the residential area in the 2 km long eastern floodplain of the creek between Lincoln Street and the Oxley Highway.

5.4 Community Consultation

The Community Consultation process provided valuable direction over the course of the investigations, bringing together views from key Council staff, other departments and agencies, and importantly, the views of the community gained through:

- The delivery of a Community Newsletter and Questionnaire to property occupiers located in the floodplain, as well as inclusion of the documentation on Council's web site to allow the wider community to gain an understanding of the issues being addressed as part of the study.
- Meetings of the Floodplain Management Committee to discuss results as they became available.
- Exhibition of the draft Study Report to give the community the opportunity to comment on the study findings and the draft *FRMP.*

5.5 Structure of Floodplain Risk Management Study and Plan

The *Blackjack Creek Floodplain Risk Management Study (FRMS)* and *draft FRMP* are supported by Appendices which provide additional details of the investigations undertaken during the investigation. A summary of the *draft FRMP* proposed for the study area is shown in **Table S.2** at the commencement of this report. The draft Plan includes five preferred measures which are given a Priority 1 ranking. They include:

- Planning and development controls for future development in flood prone areas (Measure 1),
- Improvements to existing flood preparedness and awareness in the Blackjack Creek community (Measures 2 and 3).
- Riparian corridor/channel improvement scheme on Blackjack Creek (Measures 4 and 5).

A priority list of alternative measures which could mitigate existing flooding conditions in the event that the riparian corridor/channel improvement scheme does not proceed is also presented in **Table S.2**. These measures could involve the investigation and construction of a flood protection levee along the eastern bank of Blackjack Creek (Measures 6 and 7), or investigation and implementation of a Flash Flood warning System (Measures 8 and 9).

5.6 Flooding Pattern and Impact

5.6.1 Flood Pattern

Figure 2.1 shows the indicative extents of flooding for the 5, 20 and 100 year ARI and the Probable Maximum Flood. **Figure B8.3** of **Appendix B** shows residential and commercial properties which would be flooded above floor level in the event of a 100 year ARI flood. The extent of flooding and inundation of flood affected properties is indicative only, being based on available contour mapping and the cross sections of the creeks and floodplains comprising the hydraulic model developed in the Flood Study, 2005. It should not be used to identify the flood affectation of individual properties, for which a site specific survey would be required.

5.6.2 Impacts of Flooding

Table 5.1 shows the number of properties which would be flooded to above floor level and the damages experienced for the various classes of property in the Blackjack Creek study area.

TABLE 5.1
ECONOMIC IMPACTS OF FLOODING
BLACKJACK CREEK STUDY AREA

Flood Event ARI	No. of Properties Flooded and Flood Damages						Total Flood Damages
	Residential		Commercial /Industrial		Public Buildings		
	No.	$ x 10^6	No.	$ x 10^6	No.	$ x 10^6	$ x 10^6
20	29	1.39	0	0	0	0	1.39
50	66	2.43	0	0	0	0	2.43
100	104	3.45	0	0	0	0	3.45
PMF	192	9.07	1	0.05	0	0	9.12

5.7 Flood Modification Measures

5.7.1 Riparian Corridor /Channel Improvement Scheme

Improvements to increase the conveyance capacity of the creek associated with the implementation of a riparian corridor are supported by the Community and are worth considering further by the Committee for inclusion in the draft *FRMP*. The riparian corridor would extend over about a 1.9 km reach between Lincoln Street and Oxley Highway. Preliminary hydraulic modelling and analysis of this scheme has been carried out using existing sources of survey data and indicative costs prepared.

Further hydrologic analysis with the benefit of additional survey information, the preparation of concept designs and refinement of the cost estimate is required to prepare a submission for Council/Government funding. A feasibility study has been included as a recommended measure in the draft *FRMP*, as the first step in the implementation of the project.

5.7.2 Flood Protection Levee

The construction of a 1.9 km flood protection levee along the right bank of the creek could be considered as an alternative to the riparian corridor/channel improvement in mitigating flooding in the event that the feasibility study and submission mentioned above is not successful in obtaining funding for that scheme. On the basis of the indicative costing prepared in the *FRMS,* the levee scheme is slightly less cost-effective and there are technical uncertainties with the channel scheme proposed for capturing and disposing of stormwater runoff from the areas on the protected side of the levee. Further investigation with the benefit of additional survey information would be required to confirm its feasibility. The principal constraint with the levee, however, is its adverse environmental impact on residents the eastern side of the creek. It would be up to 2 m in height and would obstruct the existing visual and physical linkage between the creek and Wandobah Road.

5.8 Property Modification Measures

The results of the *Floodplain Risk Management Study* indicate that an important measure for Gunnedah Shire Council to adopt in the floodplain would be strong floodplain management planning applied consistently by all branches of Council. A *Flood Policy* was prepared by Council following the recommendations of the Gunnedah and Carroll *FRMS* (SMEC, 1999). The

Flood Policy deals with flooding on the Namoi River, but could be adopted with minor amendments for Blackjack Creek.

The building and development controls set out in the *Flood Policy* involve the imposition of measures aimed at flood proofing future developments in flood affected areas. They include the specification of:

- Minimum habitable floor levels for residential and commercial and industrial developments (including appropriate freeboard provision);
- Appropriate flood compatible building materials.
- Egress routes from buildings.

The floodplain of Blackjack Creek has been divided into four zones according to the level of the flood risk. The approximate extents of the various **Flood Risk Zones** are shown in **Figure 2.5** and comprise:

- ***Floodway***. This is the area within the envelope of land subject to a High Flood Hazard and Floodway categorisation in a 100 year ARI flood, defined in accordance with the criteria outlined in the *Flood Study, 2005* and the *Floodplain Risk Management Study, 2010*. In the ***Floodway*** high flood damages, potential risk to life and evacuation problems may be expected. The **Floodway** extends eastwards from the creek to Wandobah Road.

- ***Intermediate Floodplain***. This is defined as the strip of land on the eastern side of Wandobah Road in which significant flow velocity and depth of inundation may be expected at the 100 year ARI level of flooding, although not sufficient to result in high hazard conditions. In this zone there would still be a significant risk of flood damages, but these damages may be minimised by the application of appropriate development controls.
- ***Flood Fringe*.** This is defined as all other land within the extent of the 100 year ARI flood. In this area flow velocities would not be significant and the depth of inundation would not be greater than 300 mm. In this zone the risk of damages is low and no flood related controls would apply to residential development, apart from the minimum floor level requirements.

- ***Outer Floodplain***. This is the remaining portion of the floodplain to the extent of the Probable Maximum Flood. There would be no flood related development controls for residential and commercial and industrial development in this zone, although Council would check proposed floor levels to ensure they were above the Flood Planning Level.

The Policy requires the minimum floor level (**Flood Planning Level**) for new residential development equal to the 100 year ARI flood, plus an allowance of 500 mm for freeboard. The Policy considers that *new development* is an unsuitable use for land which is located in the **Floodway**.

Development in the **Intermediate Floodplain** could result in an adverse re-direction of flows towards existing developments, unless precautions were taken to prevent this occurrence. Accordingly, the Policy requires development to be designed to minimise obstructions to the passage of floodwaters by ensuring that the development does not restrict the passage of overland flow through the allotment. This requirement will reduce the potential for flood damages to adjacent development.

The Policy recommends that Flood Vulnerable Development such as housing for aged persons and people with disabilities be preferably excluded from the floodplain, or at least have minimum floor levels above the PMF level.

The ***Flood Policy*** is based on the recognition that individual developments should not be evaluated in isolation, but rather, should be considered in a strategic sense as if it were one of several developments in the area. Whilst individual developments in isolation may not have a measurable impact on flooding, the cumulative impacts of ongoing development could be significant.

New buildings or additions to existing buildings would be subjected to building controls with the long term objective of mitigating flood affectation to all buildings in the floodplain. The Policy recognises that controls need to be imposed on a merit basis, balancing restrictive development conditions with the impact of development on flood behaviour in the floodplain.

5.9 Indicative Flood Extents

The plans showing the extents of flooding and flooded properties (**Figure 2.1**) are indicative only, being based on available 2 m contour mapping and limited cross sections of the creeks and their floodplains. This level of accuracy in the flood mapping is supported by DECCW, as the costs associated with undertaking detailed ground survey in each flood affected property presently lies outside the scope of the NSW Government's floodplain program.

Under the program, it is Council's responsibility to identify the flood risk within the floodplain and prepare maps showing indicative flood extents, with the onus being on the property owner to carry out sufficient survey to allow a more accurate picture of flood affection to be described in his allotment.

To allow Council to assess individual development proposals, a detailed site survey would be required to allow the extent of flooding and the flood hazard to be evaluated using the results of the Blackjack Creek Flood Study. For this reason, applicants will be required to submit a detailed survey plan of the site for which development is proposed.

5.10 Voluntary Purchase of Residential Property

Removal of housing is a means of correcting previous decisions to allow buildings in high hazard areas in the floodplain. The voluntary purchase of residential property in hazardous areas has been part of subsidised floodplain management programs in NSW.

The review undertaken in the *FRMS* showed that implementation of a Government sponsored voluntary purchase scheme was not economically viable and could not be justified on social grounds.

5.11 Raising Floor Levels of Residential Property

The analysis undertaken in the *Floodplain Risk Management Study* showed that the implementation of a voluntary house raising program was not economically viable and could not be justified on social grounds.

5.12 Response Modification Measures

5.12.1 Flood Warning and Response

The floor levels of properties potentially affected by flooding have been surveyed, or estimated from available topographic survey. Plans have been prepared as part of this present study, showing the indicative extent of flooding, high hazard areas and the locations of flooded properties. Plans showing the expected rate of rise of floodwaters have also been prepared. Consequently there is information available to identify areas at risk from flooding for the full range of flood events likely to trigger flood response procedures .

The Gunnedah Local Flood Plan, 2002 should be reviewed and further developed by SES so as to produce a graded response plan involving:

- Ranking the threatened houses according to their hazard situation, taking account of depth and velocity of floodwaters, and means of access, as a flood develops.
- Preparing a detailed response plan which focusses on initial evacuations from the most hazardous locations, followed by further evacuations in descending exposure to hazardous conditions.
- Preparing a plan for traffic management, which takes account of the sequence of road flooding as a flood develops. This plan would aim to:
  - maximise opportunities for the community to evacuate,
  - prevent unnecessary traffic through the affected area,
  - ensure access for SES operations.

5.12.2 Flood Awareness

A number of measures are recommended to maintain awareness in the community of the threat posed by floods:

- The proposed amendments to the Flood Policy should be considered, amended as required and adopted by Council.
- Council should continue to promote knowledge of the characteristics of flooding among the affected property owners. These characteristics should include information on the frequency of flooding and the depths at various locations. Council and SES should incorporate this information and the data derived from **Section 5.12.1** above in a FloodSafe Brochure to inform residents of the flood risk, which could be distributed with the rate notices. The community should also be made aware that a flood greater than historic levels or the planning level can, and will, occur at some time in the future. The need for a flood response and preparedness plan to address such an occurrence should be clearly explained.
- The *Floodplain Risk Management Plan* should be publicised and exhibited in Council offices and at community gathering places to make residents aware of the measures being proposed.

5.12.3 Flash Flood Warning System

In the event that neither of the two structural flood mitigation measures (riparian corridor/channel improvement or the flood protection levee) proceeds in a reasonable timeframe, a *Flash Flood Warning* system as outlined in **Section 3.9** could be considered. A study would be required to confirm its feasibility prior to its implementation. Both the feasibility study and implementation of the system would qualify for Government funding assistance.

5.13 Recommended Measures and Funding

Broad funding requirements for the recommended measures to be included in the *draft FRMP* are given in **Table S.2**. These measures comprise a program of engineering investigations and capital works, preparation of planning documentation by Council, and community education on flooding by SES and Council to improve flood awareness and response. They will over time, achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

5.14 Implementation Program

The steps in progressing the floodplain management process are:

- Floodplain Management Committee to consider and adopt recommendations of this study. In particular, the Committee have reviewed the basis for ranking floodplain management measures (as set out in **Table 4.1** of the *FRMS* and the proposed works and measures to be included in the draft *FRMP* as set out in **Table S.2**).
- Exhibit the *draft FRMS* and *FRMP* and seek community comment.
- Consider public comment, modify the document if and as required, and submit the final document to Council.
- Council adopts the *FRMP* and submits an application for funding assistance from the Floodplain Management Program administered by DECCW and/or the Natural Disaster Mitigation Program administered by the State Emergency Management Committee and other agencies.
- As funds become available from DECCW, other Government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

The *FRMP* should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of Council's planning strategies and importantly, the outcome of some of the studies proposed in this report as part of the *FRMP*. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the *FRMP*

6 DEFINITIONS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government's *Floodplain Development Manual, 2005*.

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The per cent probability of occurrence of a flood equal to or greater than a particular magnitude. For example, the 100 year ARI flood has a 1% chance (i.e a one-in-100 chance) of being equalled or exceeded in any one year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Probable Maximum Flood	The maximum possible flood that could reasonably be expected to occur at a particular location.
Floodplain	The area inundated by the **Probable Maximum Flood**.
Flood Planning Level (*FPL*) – Blackjack Creek	Flood levels selected for planning purposes, as determined in the Blackjack Creek Flood Study, 2005 and referenced in the *Floodplain Risk Management Study, 2010* and associated *Floodplain Risk Management Plan*. For residential development in the floodplain, it is the flood level derived from the 100 year ARI flood event, plus the addition of a 500 mm Freeboard. Essential Community Facilities (eg. schools, hospitals), Critical Infrastructure and Flood Vulnerable Development (eg housing for Aged Persons and people with disabilities) should be excluded from the floodplain or at least have minimum floor levels equal to that of the PMF.
Flood Prone/Liable Land	Land susceptible to flooding up to **Probable Maximum Flood**.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods, they are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels.
Freeboard	The factor of safety usually expressed as a height above the peak level of the Planning Level flood. Freeboard allows for factors such as wave action, localised hydraulic effects, greenhouse and climatic change, as well as accuracy of flood modelling data. The default value for freeboard is 500 mm unless a site specific freeboard to take account of localised effects is agreed to by Council.

TERM	DEFINITION
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

7 REFERENCES

Lyall and Associates Consulting Water Engineers, 2005. *"Blackjack Creek Flood Study"*.

New South Wales Government, 2005. *"Floodplain Development Manual: the Management of Flood Liable Land"*.

Gunnedah Shire Council, *"Gunnedah Local Environmental Plan, 1998 (Updated 2008)"*.

Snowy Mountains Engineering Corporation, 1999. *"Gunnedah and Carroll Floodplain Management Study and Plan"*.

State Emergency Service, NSW, 2002. *"Gunnedah Local Flood Plan"*.