Appendix G

Riparian Corridor and Site Flood Assessment by Worley Parsons

WorleyParsons
resources & energy

EcoNomics

165 – 185 RIVER ROAD, TAHMOOR

RIPARIAN CORRIDOR AND SITE FLOOD ASSESSMENT

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Project: 301015-02294
165 – 185 RIVER ROAD, TAHMOOR RIPARIAN CORRIDOR AND SITE FLOOD ASSESSMENT

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1. INTRODUCTION

The property at 165 – 185 River Road, Tahmoor is a 110 hectare site located approximately 2 kilometres south-east of the township of Tahmoor, as shown by the red site boundary in **Figure 1**. The site is to be zoned Rural Landscape (*RU2*) under the new Wollondilly Local Environmental Plan 2010 (*LEP*) and a majority of the site can be classified as arable farmland.

Aerial photography and mapping obtained from the NSW Land and Property Management Authority's (*LPMA*) Spatial Information Exchange (*SIX Viewer*) indicates that there are a number of farm dams and streams located within and in the vicinity of the site (*refer* **Figure 1**). Where required, measures need to be taken to provide appropriate riparian corridor setbacks for any future development to protect and preserve riparian vegetation and habitat.

There is also potential for flooding from these watercourses, including the Upper Nepean River, Bargo River and Myrtle Creek to encroach into the site (*refer* **Figure 1**). Development within the site would be constrained by the area affected by flooding and the associated flood planning restrictions imposed by Wollondilly Shire Council according to the requirements of the NSW Floodplain Development Manual (*2005*).

Accordingly, WorleyParsons has been engaged to determine the constraints for the property associated with the existing watercourses within and around the site and the potential for flooding to occur along these watercourses, including the Upper Nepean River, Bargo River and Myrtle Creek.

The basis of the following report was a detailed ground-truthing investigation in order to verify the presence and environmental value of any streams and to provide recommendations on riparian setbacks that will apply to any future development. Investigations also involved a desktop analysis of the potential for flooding to affect the site. The results of these investigations are outlined in the following.

2. RIPARIAN CORRIDOR GUIDELINES

The environmental value of riparian land within and adjacent to a watercourse is to be considered in determining the required riparian corridor width that is to be preserved and protected.

The NSW Office of Water (*a part of the Department of Environment, Climate Change and Water and formerly known as the Department of Water & Energy*) has previously prepared stream classification mapping for several areas across NSW. This classification system has been used to determine whether a stream is assigned a Category 1, 2 or 3 classification, which is a reflection of the environmental value of the watercourse and its capacity to provide riparian habitat.

The Department has since released a series of guideline documents for controlled activities within waterfront land, which are now regulated under the Water Management Act 2000 (*WMA*). The document titled, *'Guidelines for Controlled Activities; Riparian Corridors'* (*DWE, 2008*) contains the most relevant information on setting riparian corridor widths.

Rather than adhering strictly to the previous and existing Category 1, 2, 3 classification system, the guideline provides recommendations on riparian corridor widths according to a more simplified classification system based on stream order. The stream ordering system is known as the Strahler System and applies the following rules:

- A watercourse is a <u>first order</u> stream from its headwaters at the top of the catchment to its confluence with another stream.
- A <u>second order</u> watercourse forms downstream from the confluence of two first order streams. The watercourse will remain a second order stream until it confluences with another second order stream, at which point it becomes a <u>third order</u> watercourse and so on.

It should be noted that adoption of this simplified approach to stream classification does not preclude the consideration of the environmental value of a watercourse when setting appropriate riparian corridor widths. The guideline recommends that riparian corridor widths should reflect a merit assessment of the site and the consideration of any impacts of the proposed activity.

Consultation with the NSW Office of Water (*NOW*) has confirmed that the guideline is a "guide" only and therefore a merits based assessment of environmental value is worthwhile in most situations (*pers. comm. Jeremy Morice at NSW Office of Water*).

A summary of the riparian corridor guideline is outlined in **Table 1**. A complete copy of the guideline is provided in **Appendix A**. As shown, the riparian corridor is separated into the Core Riparian Zone (*CRZ*) and the Vegetated Buffer (*VB*). The bushfire Asset Protection Zone (*APZ*) is to be considered as a separate and additional buffer for development.

TABLE 1 SUMMARY OF NSW OFFICE OF WATER RIPARIAN CORRIDOR GUIDELINES

RIPARIAN CORRIDOR ZONE AND OBJECTIVES	ZONE WIDTH REQUIREMENTS
Core Riparian Zone (*CRZ*) The land within, or adjacent to the channel. A CRZ should remain, or become vegetated, with fully structured native vegetation (*including groundcovers, shrubs and trees*). The width of the CRZ from the banks of the stream is determined by assessing the importance and riparian functionality of the watercourse, merits of the site and long-term use of the land. There should be no infrastructure such as roads, drainage, stormwater structures, services, etc. within the CRZ.	▪ For any first order watercourse, and where there is a defined channel where water flows intermittently, the CRZ should be **10 metres wide**. ▪ For any permanently flowing first order watercourse, or any second order watercourse, the CRZ should be **20 metres wide**. ▪ For any third order or greater watercourse, and where there is a defined channel where water flows intermittently or permanently, the CRZ should be **20 – 40 metres wide**.
Vegetated Buffer (*VB*) Protects the environmental integrity of the CRZ from weed invasion, micro-climate changes, litter, trampling and pollution: There should be no infrastructure such as roads, drainage, stormwater structures, services, etc. within the VB.	The recommended width of the VB is **10 metres** but this depends on merit issues.
Asset Protection Zone (*APZ*) APZ's are a requirement of the NSW Rural Fire Service and are designed to protect assets (*houses, buildings, etc.*) from potential bushfire damage. The APZ should contain cleared land which means that it can not be part of the CRZ or VB. Infrastructure such as roads, drainage, stormwater structures, services, etc. can be located within APZs.	Widths as per NSW Rural Fire Service requirements, not discussed as part of this report. Provision of the APZ must not result in clearing of the CRZ or VB.

Source: Guidelines for Controlled Activities: Riparian Corridors (DWE, 2008)

The NSW Office of Water (*NOW*) has indicated that the streams identified on the current LPMA mapping (*refer* **Figure 1**) have not been classified according to the Category 1, 2, 3 classification system previously used by the Department (*pers comm. Jeremy Morice at NSW Office of Water*).

Accordingly, NOW has recommended that the riparian corridor guidelines outlined in **Table 1** are to be followed in the assessment of riparian corridor widths for the site at 165 – 185 River Road.

The guideline indicates that the classification of watercourses using the Strahler System is to be based on the streams included on current 1:25,000 scale topographic maps (*refer* **Appendix A**).

Review of the topographic map for the area has revealed that the streams identified in the LPMA mapping are the same as those included on the topographic map (*refer* **Figure 1**) and therefore, it is likely that the LPMA mapping is based on the topographic map.

It is understood that the stream mapping shown on the 1:25,000 scale topographic maps is typically developed via a desktop style analysis using ground contour information and therefore, may not truly reflect the "on-ground" conditions at the site.

The recent aerial photography shown in **Figure 1** also indicates that the existing stream mapping may not be an accurate representation of the "on ground" conditions.

Accordingly, it was determined that ground-truthing investigations were required to verify the presence of the mapped streams and assess their environmental value as riparian habitat, the results of which would form the basis for assigning appropriate riparian corridor widths. The details and findings of these site investigations are documented in the following sections.

As shown in **Table 1** and **Appendix A**, the Riparian Corridors Guideline (*DWE, 2008*) correlates the Strahler stream order to the required riparian corridor width. It further indicates that a merits based assessment is also appropriate in setting the CRZ and VB width.

However, the guideline does not provide specific details to be considered in the merits based assessment; nor does it directly correlate the specific environmental attributes of a stream to a required riparian corridor width.

For additional guidance in the merits based assessment, reference was also made to the previous stream classification system commonly used by the Department (*i.e., the Category 1, 2, 3 system*). A summary of this classification system and the associated setbacks for riparian land is outlined in **Table 2**. As an example, this system is the same or similar to that adopted in the report titled, '*Riparian Corridor Management Study; Covering all of the Wollongong Local Government Area and Calderwood Valley (DIPNR, 2004).*

As shown, the information contained in **Table 2** draws a more direct correlation between environmental attributes and riparian corridor width requirements.

Comparison of the information contained in **Tables 1** and **2** indicates that a Category 1 stream requires similar setbacks as a third order or greater watercourse. In this way, a Category 2 stream can be likened to a second order stream, or a permanently flowing first order stream. A Category 3 stream can be considered to be equivalent to a first order stream where water flows intermittently.

TABLE 2 STREAM CLASSIFICATION SYSTEM COMMONLY ADOPTED

CATEGORY	CLASSIFICATION AND OBJECTIVES	RIPARIAN CORRIDOR WIDTH
1	<u>Environmental Corridor</u> Maximise the protection of terrestrial and aquatic habitat to: ▪ provide a continuous corridor width for the movement of flora and fauna; ▪ provide extensive habitat (*and connectivity between habitat nodes*) for terrestrial and aquatic fauna; ▪ Maintain the viability of native riparian vegetation; ▪ Manage edge effects at the riparian/urban interface; ▪ Provide bank stability; ▪ Protect water quality.	Minimum width: ▪ a CRZ width of **40 metres** (*measured from the top of bank*) along both sides of the watercourse ▪ plus a **10 metre** wide Vegetated Buffer
2	<u>Terrestrial and Aquatic Habitat</u> Maintain or restore the natural functions of a stream and its aquatic and terrestrial values to: ▪ Maintain the viability of native riparian vegetation; ▪ Provide suitable habitat for terrestrial and aquatic fauna; ▪ Provide bank stability; ▪ Protect water quality.	Minimum width: ▪ a CRZ width of **20 metres** (*measured from the top of bank*) along both sides of the watercourse ▪ plus a **10 metre** wide Vegetated Buffer.
3	<u>Bank Stability and Water Quality</u> Maintain or restore as much as possible the natural functions of a stream to: ▪ Provide bank stability; ▪ Protect water quality; ▪ Protect native vegetation.	Minimum width: ▪ a CRZ width of **10 metres** (*measured from the top of bank*) along both sides of the watercourse ▪ no Vegetated Buffer is required

Source: *<u>Riparian Corridor Management Study (DIPNR, 2004)</u>*

3. STREAM GROUND-TRUTHING

A detailed site inspection was undertaken on 26th July 2010 to assess the watercourses identified in the LPMA and topographic mapping (*refer* **Figure 1**). The inspections targeted the assessment of a variety of "on-ground" criteria, relating to both the physical presence of the watercourses and their capacity to meet the environmental objectives outlined in **Table 1** and **Table 2**.

The following features were assessed for each watercourse:

- the stream order, according to the Strahler System;
- the presence of a defined channel (*either intermittent or continuous*) along the alignment of the watercourse;
- the extent of riparian vegetation, specifically:
  - the presence of vegetation with environmental value, such as native species
  - the presence of noxious weeds and degree of weed infestation
- the presence of any ponded water;
- the presence of flow along the stream and the associated flow velocity;
- the presence of any aquatic or terrestrial fauna; and,
- the potential connectivity between any riparian vegetation and upstream or downstream riparian corridors.

The site investigations also involved the identification of any additional watercourses or dams not previously included in the LPMA mapping. The complete set of watercourses that were assessed is shown in **Figure 2**. Each stream or farm dam has been assigned a number.

Based on the observations made during site investigations and through comparison with the criteria outlined in **Table 1** and **Table 2**, several recommendations have been made regarding the required riparian corridor widths within and adjacent to the site. These are documented in the following section.

4. RECOMMENDATIONS

4.1 UPPER NEPEAN RIVER

The Upper Nepean River passes parallel to the eastern boundary of the site as it flows north (*refer* **Figure 2**). The river borders a 400 metre length of the eastern-most site boundary downstream from its confluence with the Bargo River.

The Upper Nepean River is major waterway that drains a catchment area of approximately 700 km^2. Although not confirmed by a detailed assessment, this river would be at least a fifth order watercourse.

The waterway has significant environmental value in the vicinity of the site, both in terms of riparian habitat and corridor connectivity. This was confirmed through visual inspection of the river from the site, although investigations did not involve exploration past the edge of the gorge. According to the NOW guidelines, it is recommended that a riparian corridor width of 50 metres apply for this river, including allowance for the Core Riparian Zone (*CRZ*) and the Vegetated Buffer (*VB*). This corridor width would apply from the top-of-bank alignment for the river.

4.2 BARGO RIVER

The Bargo River confluences with the Upper Nepean River near the south-east corner of the site (*refer* **Figure 2**). The river borders a 300 metre section of the boundary upstream from this location.

The Bargo River drains a catchment of about 140 km^2, and would be classified as a fifth order watercourse or greater. It is also considered to be a major waterway with significant environmental value and offers both riparian habitat and corridor connectivity. According to the NOW guidelines, it is recommended that a riparian corridor width of 50 metres be applied to this river, to be taken from the top-of-bank alignment.

4.3 MYRTLE CREEK

Myrtle Creek passes parallel to the northern boundary of the site as it flows towards the Upper Nepean River (*refer* **Figure 2**). The creek comes closest to the site along a 200 metre length of the boundary at the north-west corner of the site.

The creek is not as major a waterway as the Upper Nepean or Bargo Rivers. However, an assessment of vegetation on available aerial photography and site observations indicate that it provides significant riparian habitat and riparian corridor connectivity between the Upper Nepean River and areas upstream along Myrtle Creek.

Accordingly, it is recommended that a minimum riparian corridor width of 30 metres be adopted for Myrtle Creek, including an allowance for the CRZ and VB. This corridor width would apply from the top-of-bank alignment for the creek.

4.4 WATERCOURSE 1

The alignment of Watercourse 1 (*W1*) as shown in the LPMA mapping is shown in **Figure 2**. It is recommended that W1 should not be classified as a watercourse for a 550 metre length between the western site boundary (*including Dam D1*) and the existing vegetation located near the eastern site boundary. Hence, no riparian corridor width will need to be provided for this section.

This recommendation is based on the following observations:

- No defined channel was observed along the length of W1;
- No overland flow or ponded water (*refer* **Plates 1** *and* **2**); and
- No riparian vegetation, except adjacent to the eastern site boundary, and hence no riparian connectivity; predominantly pasture grass only (*refer* **Plates 1** *and* **2**).

It should be noted that a designated stormwater flow-path will need to be retained along the gully or a similar alignment as part of any future development, to allow for the drainage of stormwater collected within this section of the site and from catchment areas upstream from Dam D1.

Plate 1: View looking west (*upstream*) along W1 towards the downstream extent of Dam D1

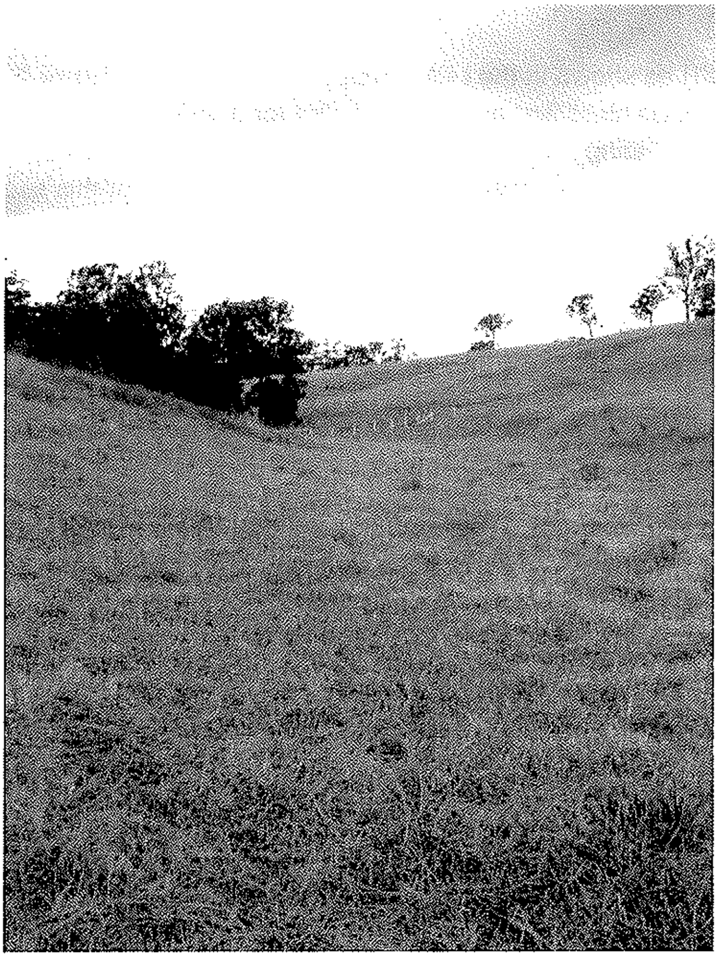


Plate 2: View looking east to where W1 crosses the eastern site boundary

It is recommended that a 140 metre length of W1 be retained immediately upstream of the eastern site boundary. A riparian corridor width of 10 metres on either side is to be provided for this section of the creek, as no permanent flow was observed along this first order watercourse.

4.5 WATERCOURSE 2

4.5.1 WATERCOURSE 2A

The alignment of Watercourse 2A (*W2A*) is presented in **Figure 2**. It is recommended that W2A should not be classified as a watercourse.

This recommendation is based on the following observations:

- No defined channel was observed along the length of W2A; and
- No riparian vegetation; pasture grass only (*refer* **Plate 3**).

Plate 3: View looking east (*downstream*) along W2A towards eastern site boundary

4.5.2 WATERCOURSE 2B

The alignment of Watercourse 2B (*W2B*) is shown in **Figure 2**. It is recommended that W2B should not be classified as a watercourse.

This recommendation is based on the following observations:

- No defined channel was observed along the length of W2B (*refer* **Plate 4**); and,
- No riparian vegetation; closely cropped pasture grass only (*refer* **Plate 4**).

Plate 4: View looking south (*downstream*) along W2B towards W2D

4.5.3 WATERCOURSE 2C

The alignment of Watercourse 2C (*W2C*) as determined by the LPMA mapping is presented in **Figure 2**. It is recommended that W2C should not be classified as a watercourse within the site boundary.

This recommendation is based on the following observations:

- No defined channel was observed along the length of W2C (*refer* **Plates 5** and **6**); and,
- No riparian vegetation, closely cropped pasture grass only (*refer* **Plates 5** and **6**).

Plate 5: View looking south-west (*upstream*) along W2C towards site boundary

Plate 6: View looking north-east (*downstream*) along W2C towards W2D

4.5.4 WATERCOURSE 2D

The alignment of Watercourse 2D (*W2D*) is shown **Figure 2**. W2D is constrained within a steep sided valley approximately 70 metres wide.

It is recommended that W2D be retained in the stream mapping for its entire 350 metre length. It is also recommended that a minimum riparian corridor width of 10 metres be provided from the top-of-bank on either side of the creek.

This recommendation is based on the following observations:

- The stream is a first order watercourse with noticeable channel definition. However, the watercourse had no permanent flow or ponded water,
- Within the steep sided valley there is significant native vegetation and riparian habitat, as evidenced by wombat holes. Moss on rocks was indicative of a microclimate cooler than the surrounding farmland (*refer* **Plates 7** *and* **8**). However, the extent of native vegetation and habitat is heavily reduced or non-existent outside of the valley and therefore, the riparian corridor width does not need to extend beyond the current extent of vegetation.

Plate 7: View looking northwest (upstream) along W2D channel

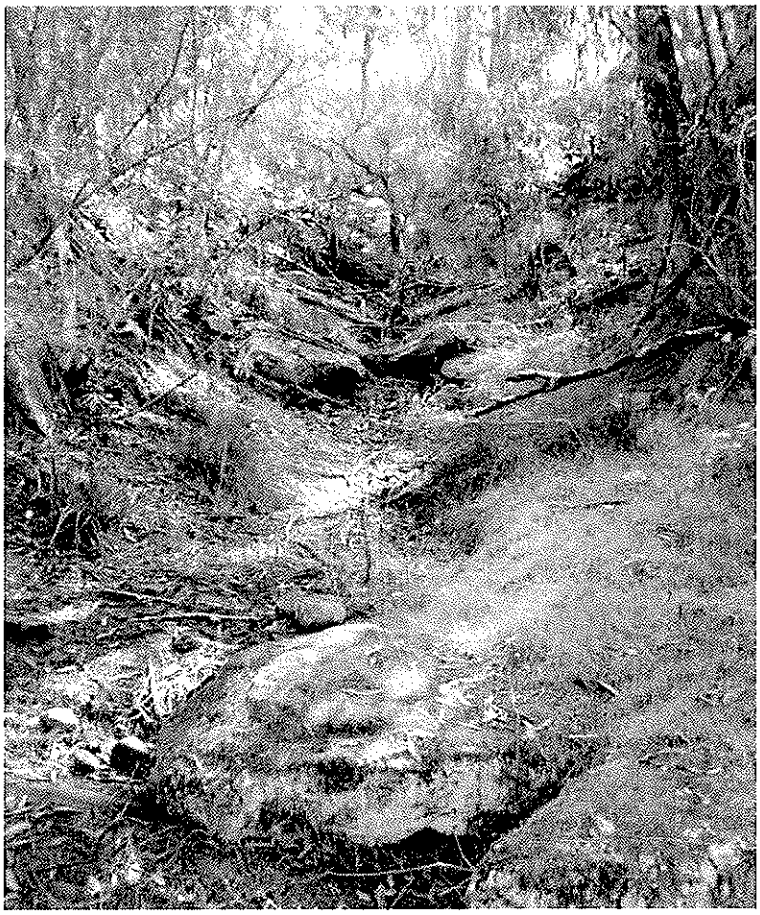


Plate 8: View looking southeast (*downstream*) along W2D channel

4.6 WATERCOURSE 3

The alignment of Watercourse 3 (*W3*) is shown in **Figure 2**. It is recommended that W3 should not be classified as a watercourse within the site boundary.

This recommendation is based on the following observations:

- No defined channel was observed along the length of W3 (*refer* **Plates 9** and **10**); and,
- No riparian vegetation; closely cropped pasture grass only (*refer* **Plates 9** and **10**).

It is recommended that a designated flow path be provided along the approximate gully alignment to allow for drainage of stormwater collected within this section of the site.

Plate 9: View looking southwest (ups*tream*) along W3

Plate 10: View looking west across W3

4.7 WATERCOURSE 4

The alignment of Watercourse 4 (*W4*) as shown in the LPMA mapping is presented in **Figure 2**. It is recommended that W4 should not be classified as a watercourse within the site

This recommendation is based on the following observations:

- No defined channel was observed along the length of W4 (*refer* **Plate 11**);
- no riparian vegetation; closely cropped pasture grass only (*refer* **Plate 11**); and,
- there is no clearly defined channels upstream or downstream from the D4 (*refer* **Plate 11**)

Plate 11: View looking west along alignment of W4

4.8 DAMS 1 TO 6

The locations of Farm Dams 1 to 6 (*D1, D2, D3, D4, D5 and D6*) as shown in the LPMA mapping and aerial photography are shown in **Figure 2**.

The site inspections confirmed that no dams exist at locations D5 or D6. It is expected that the dams have "dried-up" since the mapping was prepared and the aerial photography was captured, as confirmed through inspection of the dam locations (*refer* **Plate 12**). The location of D5 as inferred by the LPMA mapping comprised open farmland and no photo of this feature was taken.

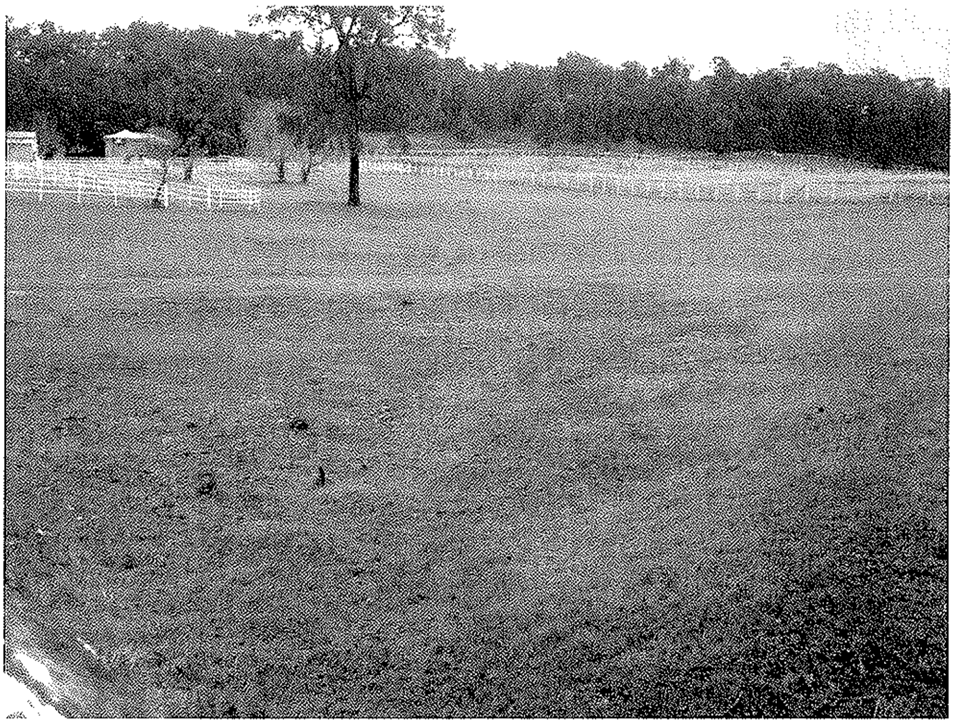


Plate 12: View looking across D6, which has dried-up since previous aerial photography was taken

Site investigations confirmed the presence of Dams D1, D2 and D3 and D4. However, it is recommended that no riparian setback is required for these dams, based on the following observations:

- the dams provide limited habitat for birds or amphibians (*ducks were observed at D1 and D2*), however;
- there are no clearly defined channels upstream or downstream from any of the dams and therefore, the dams do not lie on any watercourses; and,
- there is limited or no vegetation connectivity upstream or downstream from the dams.

Furthermore, it is evident that the dams are all man-made and have been constructed as part of past and current farming activities at the site. Accordingly, it is recommended that the dams could be removed as part of any future development of the site, if required. Dams 1 to 4 are shown in **Plates 13** to **16**, respectively.

Plate 13: View looking west across D1 to site boundary

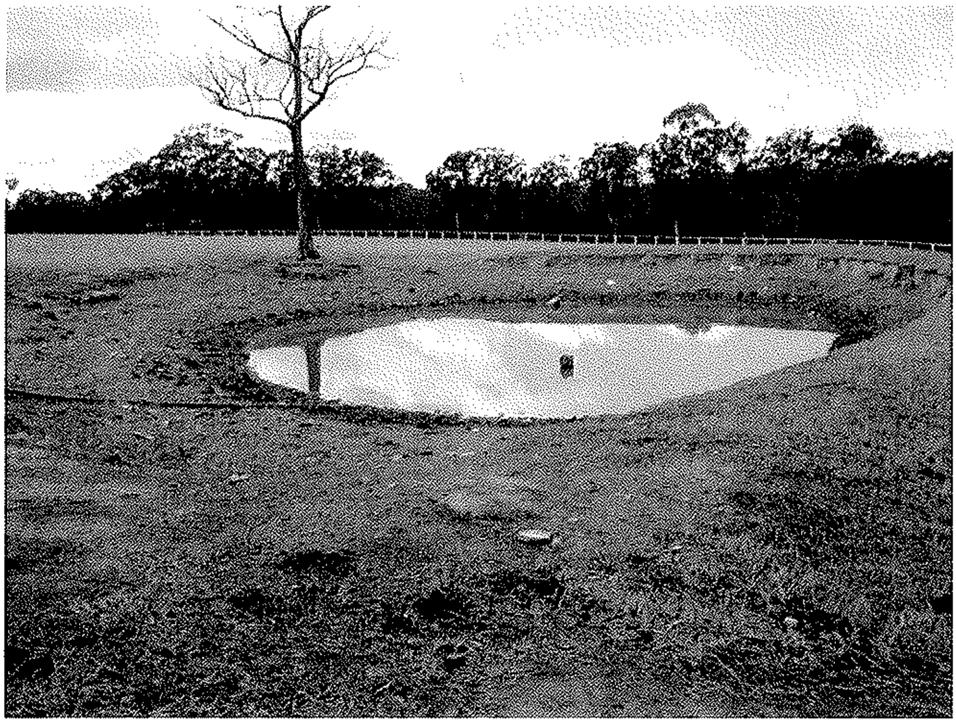


Plate 14: View looking east to D2

Plate 15: View looking north to D3

Plate 16: View looking west and upstream of D4

4.9 SUMMARY

As discussed above, site investigations were undertaken to establish whether streams and dams shown in the NSW Land and Property Management Authority's Spatial Information Exchange mapping actually exist within the site at 165 – 185 River Road, Tahmoor.

The investigation involved an assessment of the identified streams against "on-ground" environmental criteria that is outlined in the guidelines from the NSW Office of Water and the previous stream classification system commonly used by the DECCW.

The results of this investigation have been used to recommend appropriate riparian corridor widths for a stream that is to be retained within the site and waterways that pass near the northern, southern and eastern property boundaries. A summary of the recommended riparian corridor widths is presented in **Figure 3**.

As shown, significant riparian corridor widths are to be provided for the Upper Nepean River and Bargo River (*50 metres*). At least 30 metres riparian corridor width is to be provided for Myrtle Creek.

It is recommended that a 140 metre length of Watercourse 1 be retained immediately upstream of the eastern site boundary, for which a riparian corridor width of 10 metres is to be provided on either side of the creek.

It is noted that the alignment of the Watercourse 1 shown in **Figure 3** may not reflect the exact on-ground location of the ephemeral stream channel. As for all stream lengths to be retained, it is recommended that the top-of-bank alignment be surveyed in detail as part of any future work to map the limit of the riparian setback within the site.

It is recommended that the remainder of Watercourse 1 and Watercourses 3 and 4 that fall within the site boundary should not be identified or classified as watercourses in any future riparian corridor mapping. However, it should be noted that alternative measures may be required to provide for the drainage of stormwater runoff from the site along similarly aligned flow-paths.

It is recommended that a riparian corridor width of 10 metres either side be retained for Watercourse 2D (*refer* **Figure 3**). However, it should be noted that the watercourse is located within a steep sided gully, which is approximately 70 metres wide. Accordingly, it is expected that adopting a riparian setback of up to 20 or 30 metres would not encroach significantly into any developable land, and would also help to retain habitat for native fauna.

It is understood that because the farm dams do not lie on any watercourses, no riparian setback would be required around the dams, should they be retained. It is also suggested that the identified farm dams could be removed as part of any future development of the site.

5. ADDITIONAL CONSIDERATIONS

The Draft Wollondilly Local Environmental Plan (*LEP*) 2009 is expected it to be adopted within the month (*around August 2010*). A particular aim of the Draft LEP is "*to protect and enhance watercourses, riparian habitats and wetlands to maintain or improve water quality*". Accordingly, the LEP identifies proposed setback distances from rivers to protect riparian areas.

The new Wollondilly Development Control Plan (*DCP*) 2010 also contains provisions for riparian setbacks. Review of the DCP has confirmed that riparian setback requirements are consistent across both planning documents.

It is understood that Council has applied the Strahler System in classifying the streams across the shire and has considered the objectives of the Riparian Corridor Guidelines contained in **Appendix A** in setting appropriate riparian corridor widths.

The associated Riparian Land Map (*Sheet RIP-022*) is presented in **Appendix B**. The mapping indicates that Council has adopted a minimum riparian corridor width of 100 metres for the Upper Nepean and Bargo Rivers. This width is greater than that recommended above (*according to the Department's guidelines*) as it is understood that special consideration has been given to the size of the upstream catchments and the importance of the rivers as significant riparian corridors. It is envisaged that Council has also considered similar riparian corridor widths that have been applied to other major waterways across NSW.

In considering the future development potential for the site it is recommended that Council's specified buffer width of 100 metres be adopted for the Upper Nepean and Bargo Rivers, to be applied from the top-of-bank alignment for the waterways. It is noted that the previously cleared land at the site is further than 100 metres from the top-of-bank alignment (*refer* **Figure 3**). In other words, any future development across areas within the existing pastureland fences would not be expected to encroach into the 100 metre wide riparian corridor for these rivers.

Based on a review of the Environmentally Significant Land map contained in the draft LEP (*2009*), it is understood that much of the existing stands of vegetation located outside of the cleared and fenced pastureland at the site is to be treated as environmentally significant (*refer Class 5 green shading in ENV-022 map,* **Appendix C**); i.e., in most instances, the edge of the environmentally significant land appears to follow the same alignment as the existing fences along the perimeter of the pasture areas.

It is understood that this mapping has been developed through consideration of vegetation corridors and connectivity, particularly along major watercourses. As such, the retention of this vegetation naturally provides the required riparian corridor widths. Notwithstanding, it is understood that future development across these areas could be undertaken, provided it does not encroach upon the riparian corridor widths discussed above. A comprehensive flora and fauna survey and a species impact assessment would also be required to satisfy Council that core vegetation and corridors are maintained. This is a requirement of the LEP/DCP for any development proposed within environmentally significant areas shown as Class 4 and 5 in the mapping (*refer* **Appendix C**).

Council's riparian corridor mapping contained in **Appendix B** shows that a minimum riparian corridor width of 30 metres is to be provided for Myrtle Creek. This is in accordance with the recommendations made as part of the assessment above.

Council has indicated that a minimum setback of 10 metres is to be provided for the watercourse identified as Watercourse 2D above (*refer* **Appendix B**). This is also in accordance with the recommendations outlined above.

The riparian corridor width for Myrtle Creek and Watercourse 2D should be taken from the top of the stream bank in accordance with the Riparian Corridor Guidelines (*DWE, 2008*).

It is noted that Council has not included in the LEP any requirements for riparian setback along the 140 metre length of Watercourse 1 that is to be retained at the eastern site boundary (*refer* **Figure 3**).

6. SITE FLOOD ASSESSMENT

6.1 BACKGROUND

As outlined above and shown in **Figure 4**, the site is bordered by Myrtle Creek to the north, the Nepean River to the east and the Bargo River to the south-east. Also shown in **Figure 4** is Watercourse 2D, which was identified by the riparian corridor assessment as a section of stream to be retained.

Flooding along these waterways can potentially inundate the site and therefore, restrict the area available for future development or place additional constraints on minimum floor levels.

The following section outlines a preliminary site flood assessment undertaken to determine the depths and extent of inundation of the site for the 100 year Average Recurrence Interval (*ARI*) flood for each of the waterways identified.

Stormwater runoff may also be concentrated along the small section of Watercourse 1 that is to be retained at the eastern site boundary (*refer* **Figure 3**). However, it is considered that this relatively minor flow would be contained within the width of the recommended riparian corridor.

It should also be noted that the other drainage flow-paths exempted as part of the riparian corridor assessment above have not been incorporated in this analysis. Provision of drainage through the site along any replacement flow-paths would need to consider the width of overland flows as part of design for any drainage works.

6.2 PREVIOUS FLOOD INVESTIGATIONS

Consultation was undertaken with Wollondilly Shire Council to determine the availability of previously completed flood investigations for the waterways in the vicinity of the site. Council has indicated that flood studies have not been completed for any of the major rivers, including the relevant sections of the Upper Nepean River, the Bargo River or Myrtle Creek.

It is understood that a Flood Study was completed for the Upper Nepean River in 1995 by the Department of Land and Water Conservation (*DLWC, now DECCW*). However, the upstream limit of the study area was at Menangle (*located approximately 15 kilometres north-east of the site*) and therefore, the Flood Study did not examine flood characteristics at the site.

Accordingly, the following assessment of flood constraints has involved a desktop analysis and is considered to offer a preliminary estimation of the peak flood flows, flow velocities and flood extents at the site.

6.3 HYDROLOGIC ANALYSIS

Catchment maps provided by the NSW Hawkesbury-Nepean Catchment Management Authority were used to estimate the upstream catchment areas draining to the Upper Nepean River, Bargo River and Myrtle Creek.

The size of the catchment draining to Watercourse 2D was determined using ground surface contour information obtained from the Land and Property Management Authority (*LPMA*).

6.3.1 Catchment Draining to Watercourse 2D

The Watercourse 2D catchment has an area of approximately 0.3 km^2 and drains the southern area of the site in a south-easterly direction into the Bargo River (*refer **Figure 4***). The catchment is mostly pasture land and extends approximately 370 metres and 110 metres beyond the western and southern site boundaries, respectively.

6.3.2 Catchment Draining to Myrtle Creek

The Myrtle Creek catchment has an area of approximately 9.6 km^2 and drains in an easterly direction to the confluence of Myrtle Creek and the Upper Nepean River (*refer **Figure 4***). While the majority of the catchment is rural farmland, the township of Tahmoor covers approximately 21% of the catchment area.

6.3.3 Catchment Draining to the Bargo River

The Bargo River catchment has an area of approximately 141 km^2 and drains in a north-easterly direction to the confluence of the Bargo and Upper Nepean Rivers (*refer* **Figure 4**). The catchment is mostly bushland and has steep gullies and gorges.

6.3.4 Catchment Draining to the Upper Nepean River

The catchment draining to the Upper Nepean River has an area of approximately 705 km^2 and drains to the confluence with the Bargo River (*refer* **Figure 4**). The catchment, which also encompasses the Burke, Avon and Cordeaux River catchments, is mostly reserved bushland and forms part of the Special Areas designated by the Sydney Catchment Management Authority.

6.3.5 Estimation of Design Flood Discharges

Peak 100 year ARI flood discharges for each of the catchments above were determined using the Rational Method outlined in *'Australian Rainfall and Runoff 1998'*. The rainfall Intensity-Frequency-Duration (*IFD*) data and the Rational Method calculations used to estimate the peak discharges are contained in **Appendices D** and **E**, respectively. The peak discharges are shown in **Table 3**.

Table 3 Predicted Peak 100 Year ARI Flood Discharges

Watercourse	Peak Discharge (m^3/s)
Watercourse 2D	6.6
Myrtle Creek	86.2
Bargo River	878
Upper Nepean River	5,600

6.4 HYDRAULIC ANALYSIS

The 100 year ARI flood levels for the waterways in the vicinity of the site were estimated through Manning's Equation style analyses at the waterway cross-sections shown in **Figure 5**. Cross-section geometry and longitudinal channel slopes were extracted from available ground surface contours from LPMA.

6.4.1 Peak Flood Levels, Velocities and Flow Widths

The peak flood levels, flow widths and velocities along the waterways were determined using the Manning's Equation for open channel flow. However, additional analysis was undertaken for Watercourse 2 to simulate flood behaviour using a HEC-RAS model of the creek. Channel slope, channel roughness and cross-section shape were determined using observations from the site visit (*where possible*) and using the LPMA contour and aerial photography data.

Peak flood levels, flow widths and velocities were calculated using Manning's style analyses at the cross-sections shown on **Figure 5**. The three cross-sections along Watercourse 2, also shown in **Figure 5**, were incorporated into the HEC-RAS model.

To assess the sensitivity of the calculated flood characteristics to the channel slope and roughness parameters, several Manning's 'n' values (*roughness coefficients*) and channel slopes were tested.

However, due to the width of the channel cross-sections relative to the flows, the resultant peak flood levels and flow velocities did not differ considerably when varying the 'n' values and a channel slopes. It was decided to adopt, "typical" roughness and slope values for each waterway to establish an indicative peak flood level, flow width and flow velocity. The results of the analyses are provided in **Table 4**.

The predicted flow widths at the cross-sections listed in **Table 4** were determined through a comparison of the predicted flood levels with the site contour data available from the LPMA mapping. It should be noted that the flood levels and flow widths contained in the table have been rounded to the nearest metre, in light of the inherent uncertainties in using the limited topographic data available in conjunction with basic Rational Method calculations to determine catchment discharge. Further assessment, including detailed hydrologic and hydraulic modelling is recommended as part of future development assessment.

Table 4 Indicative Peak Flood Levels, Flow Widths and Velocities for 100 Year ARI Flood

Cross-Section	Manning's 'n' (*in-channel*)	Stream Slope (*%*)	Approximate Peak:		
			Flood Level (*mAHD*)	Flow Width (*metres*)	Flow Velocity (*m/s*)
Confluence of Bargo & Upper Nepean Rivers (*N1*)	0.05	0.8	113	130	6.3
Bargo River (*B1*)	0.10	2.0	114	60	3.4
Myrtle Creek (*M2*)	0.10	8.0	181	26	2.9
Myrtle Creek (*M1*)	0.10	28	111	27	4.2
Watercourse 2D (*XS 3*)	0.03	6.0	191*	9	2.8*
Watercourse 2D (*XS 2*)	0.03	6.0	181*	9	2.8*
Watercourse 2D (*XS 1*)	0.03	6.0	180*	9	2.8*

** HEC-RAS Output*

It should also be noted that the predicted flow widths are applied across the entire river cross-section, as opposed to the recommended riparian setbacks, which are specified from the top-of-bank on either side of the waterway.

The extent of inundation during the 100 year ARI flood along each watercourse is <u>not</u> predicted to encroach across the site to an area greater than that required by the riparian setbacks determined through the riparian corridor assessment outlined in previous sections.

Furthermore, it should be noted that the Bargo and Upper Nepean Rivers (*and to a lesser extent, Myrtle Creek*) are located within a deep valley or gorge and therefore, the 100 year ARI flood extent is not likely to overtop the top-of-gorge for any of the waterways. As an example, the top-of-gorge level at the site adjacent to the confluence of the Upper Nepean and Bargo Rivers is about 80 metres higher than the predicted 100 year ARI flood level.

Accordingly, it is likely that the extent of flooding will not encroach across the higher, less steep sections of land at the site (*i.e., the more readily developable areas*).

6.5 CONCLUSIONS

Flooding of Watercourse 2D, Myrtle Creek, the Bargo River and the Upper Nepean River during their respective 100 year ARI flood events is not predicted to inundate a major portion of the site. The flood extents are predicted to be limited to within the channel (*or valley or gorge*) of all of the waterways investigated.

It must be noted that the flow widths and flood levels provided in this assessment have been estimated using simplified channel cross-section representations that were observed during site inspections and broad-scale catchment data extracted from LPMA. The predicted flood levels, stream flow velocities and extents are therefore indicative only, and should be used as a guide for the planning of future development options rather than the basis for the detail design of any future development.

A detailed survey of creek cross-sections and/or Airborne Laser Scanning (*ALS*) survey of the upstream catchments would be required to obtain a more reliable prediction of flood characteristics during the 100 year ARI event.

Notwithstanding, the peak 100 year ARI flood extent is not expected to inundate a greater portion of the site than would be required by the riparian setbacks for the watercourses identified in Sections 2 to 5 of this report.

7. REFERENCES

- Department of Infrastructure, Planning and Natural Resources (*2004*), '*Riparian Corridor Management Study; Covering all of the Wollongong Local Government Area and Calderwood Valley*', prepared for Wollongong City Council.

- Hawkesbur y-Nepean Catchment Management Authority website http://www.hn.cma.nsw.gov.au/ (*cited 6th August 2010*)

- NSW Government Department of Water and Energy (*2008*), '*Guideline for controlled activities: Riparian corridors*'.

- NSW Land and Property Management Authority's (*LPMA*) Spatial Information Exchange (*SIX Viewer*) http://imagery.maps.nsw.gov.au/ (*cited 28th July 2010*)

- The Institution of Engineers (*1998*), '*Australian Rainfall and Runoff 1998*'.

- Wollondilly Shire Council (*2009*), '*Draft Wollondilly Local Environmental Plan*'

- Wollondilly Shire Council (*2010*), '*Wollondilly Development Control Plan*'

Appendix A - Guidelines for Controlled Activities – Riparian Corridors

February 2008

Guidelines for controlled activities
Riparian corridors

Controlled activities carried out in, on or under waterfront land are now regulated by the *Water Management Act 2000* (WMA). The Department of Water and Energy is required to assess the impact of a controlled activity to ensure that minimal harm will be done to any waterfront land, ie. the bed and a distance inland of 40 metres from a river, lake or estuary.

This means that a controlled activity approval must be obtained from the Department prior to carrying out a controlled activity.

Riparian land forms a transition zone between terrestrial and aquatic environments and perform a range of important environmental functions. Riparian corridors:

- provide bed and bank stability and reduce bank and channel 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
- provide connectivity between wildlife habitats
- allow for conveyance of flood flows and control the direction of flood flows
- provide an interface between developments and waterways.

The protection or restoration of vegetated riparian areas is important to maintain or improve the geomorphic form and ecological functions of watercourses through a range of hydrologic conditions in normal seasons and also in extreme events.

When determining an appropriate width for a riparian corridor and how much riparian vegetation should be protected or re-established on a site, the following three riparian corridor zones (Figure 1) should be considered.

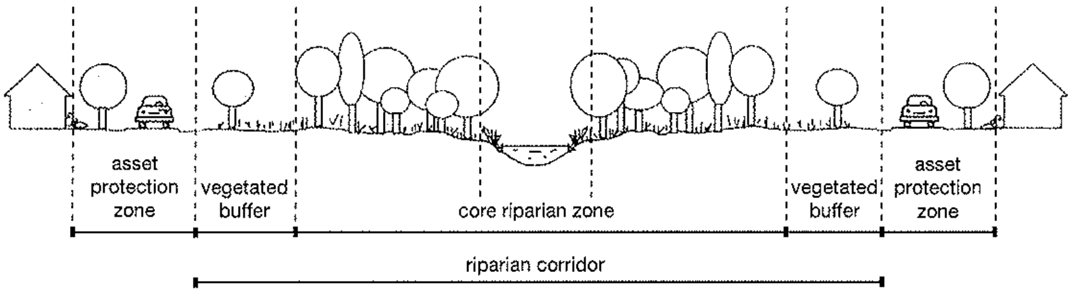
1. A **Core Riparian Zone** (CRZ) is the land contained within and adjacent to the channel. The Department wil seek to ensure that the CRZ remains, or becomes vegetated, with fully structured native vegetation (including groundcovers, shrubs and trees). The width of the CRZ from the banks of the stream is determined by assessing the importance and riparian functionality of the watercourse (Table 1), merits of the site and long-term use of the land. There should be no infrastructure such as roads, drainage, stormwater structures, services, etc. within the CRZ.

2. A **Vegetated Buffer** (VB) protects the environmental integrity of the CRZ from weed invasion, micro-climate changes, litter, trampling and pollution. There should be no infrastructure such as roads, drainage, stormwater structures, services, etc. within the VB. The recommended width of the VB is 10 metres but this depends on merit issues.

3. An **Asset Protection Zone** (APZ) is a requirement of the NSW Rural Fire Service and is designed to protect assets (houses, buildings, etc.) from potential bushfire damage. The APZ is measured from the asset to the outer edge of the vegetated buffer (VB). The APZ should contain cleared land which means that it can not be part of the CRZ or VB. The APZ must not result in clearing of the CRZ or VB. Infrastructure such as roads, drainage, stormwater structures, services, etc. can be located within APZs.

NSW Government
Department of Water & Energy

Figure 1. Riparian corridor zones.



The Department recommends that a vegetated CRZ width based on watercourse order[1] be considered in the design of any controlled activity (see Table 1). However, the final CRZ width will be determined after a merit assessment of the site and consideration of any impacts of the proposed activity. CRZ widths should be measured from the top of the highest bank and on both sides of the watercourse.

Table 1. Recommended CRZ widths.

Types of watercourses	**CRZ width**
any first order[1] watercourse and where there is a defined channel where water flows intermittently	10 metres
• any permanently flowing first order watercourse, or • any second order[1] watercourse and where there is a defined channel where water flows intermittently or permanently	20 metres
any third order[1] or greater watercourse and where there is a defined channel where water flows intermittently or permanently. Includes estuaries, wetlands and any parts of rivers influenced by tidal waters.	20 – 40 metres[2]

[1] as classified under the Strahler System of ordering watercourses and based on current 1:25 000 topographic maps

[2] merit assessment based on riparian functionality of the river, lake or estuary, the site and long-term land use.

Further information

If you require more information about controlled activity approvals please contact your local DWE office or visit our website www.dwe.nsw.gov.au

Important notes

DWE has prepared these guidelines in good faith. In the case of any inconsistency between the guidelines and the controlled activity approval or legislation, the controlled activity approval or legislation will prevail to the extent of that inconsistency.

Nothing in these guidelines is taken to authorise a controlled activity. These guidelines are designed to provide information to assist in the design of any development or work that constitutes a controlled activity and the preparation of an application for a controlled activity approval. Users are advised to seek professional advice and to refer to the legislation and any relevant approvals, as necessary, before taking action in relation to any matters covered by the guidelines.

Disclaimer

DWE 07_226f
www.dwe.nsw.gov.au

Appendix B - Wollondilly Local Environmental Plan Riparian Land Map (RIP-022)

Wollondilly Local Environmental Plan 2009

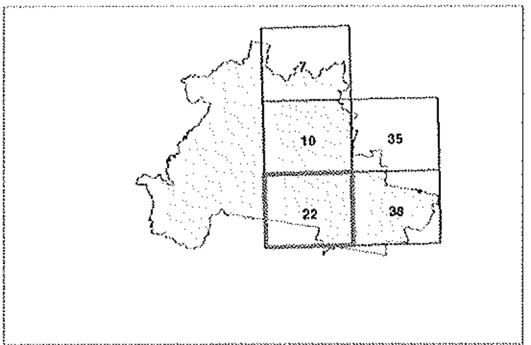
Riparian land map - Sheet RIP-022

Riparian Land

- 10m
- 30m
- 50m
- 100m

Cadastre

Cadastre 22/6/09 © Dept of Lands



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0 800 1,600 2,400 3,200
Metres
Scale 1:80,000 @ A3

Projection GDA 1994
Zone 56

Map identification number:
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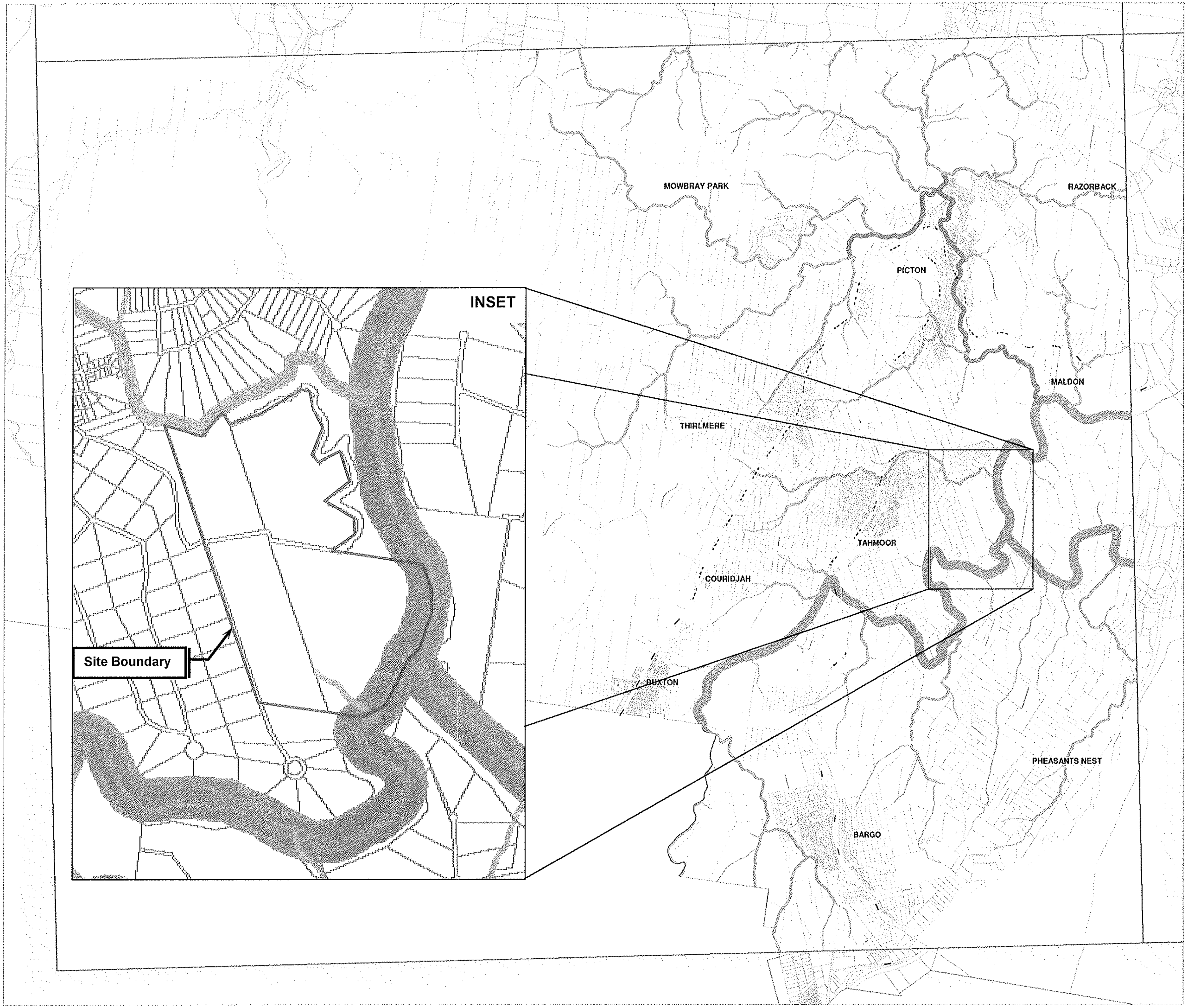


Appendix C - Wollondilly Local Environmental Plan Environmentally Significant Land Map (ENV-022)

Wollondilly Local Environmental Plan 2009

WOLLONDILLY SHIRE COUNCIL

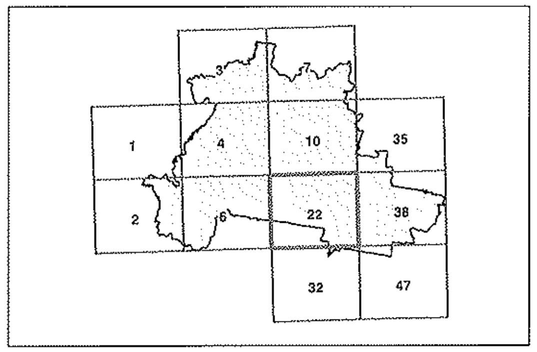
Environmentally significant land map - Sheet ENV-022

Vegetation Classification

- Class 1
- Class 2
- Class 3
- Class 4
- Class 5

Cadastre

- Cadastre 22/6/09 © Dept of Lands



N W E S

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Metres
Scale 1:80,000 @ A3

Projection GDA 1994
Zone 56

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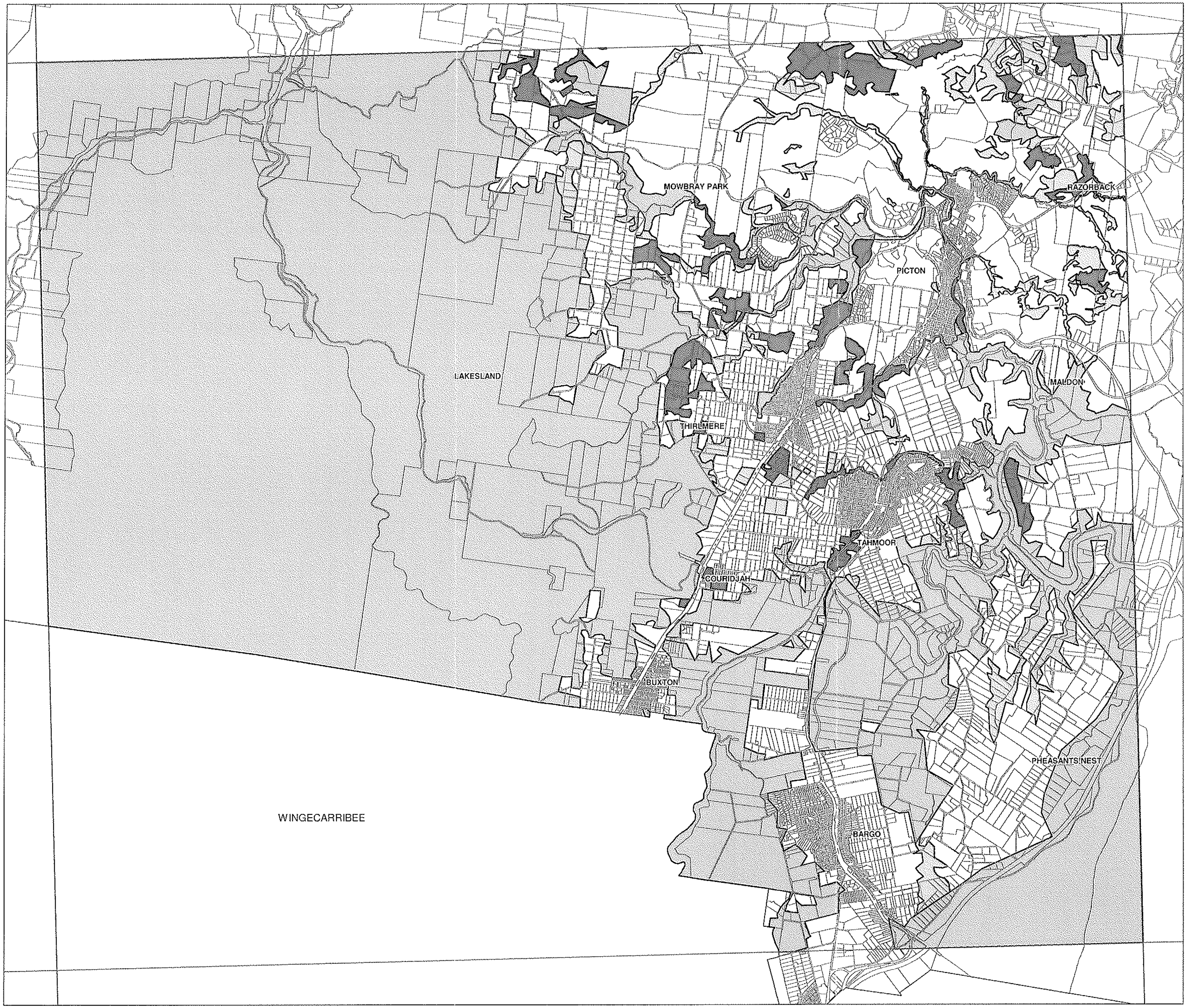
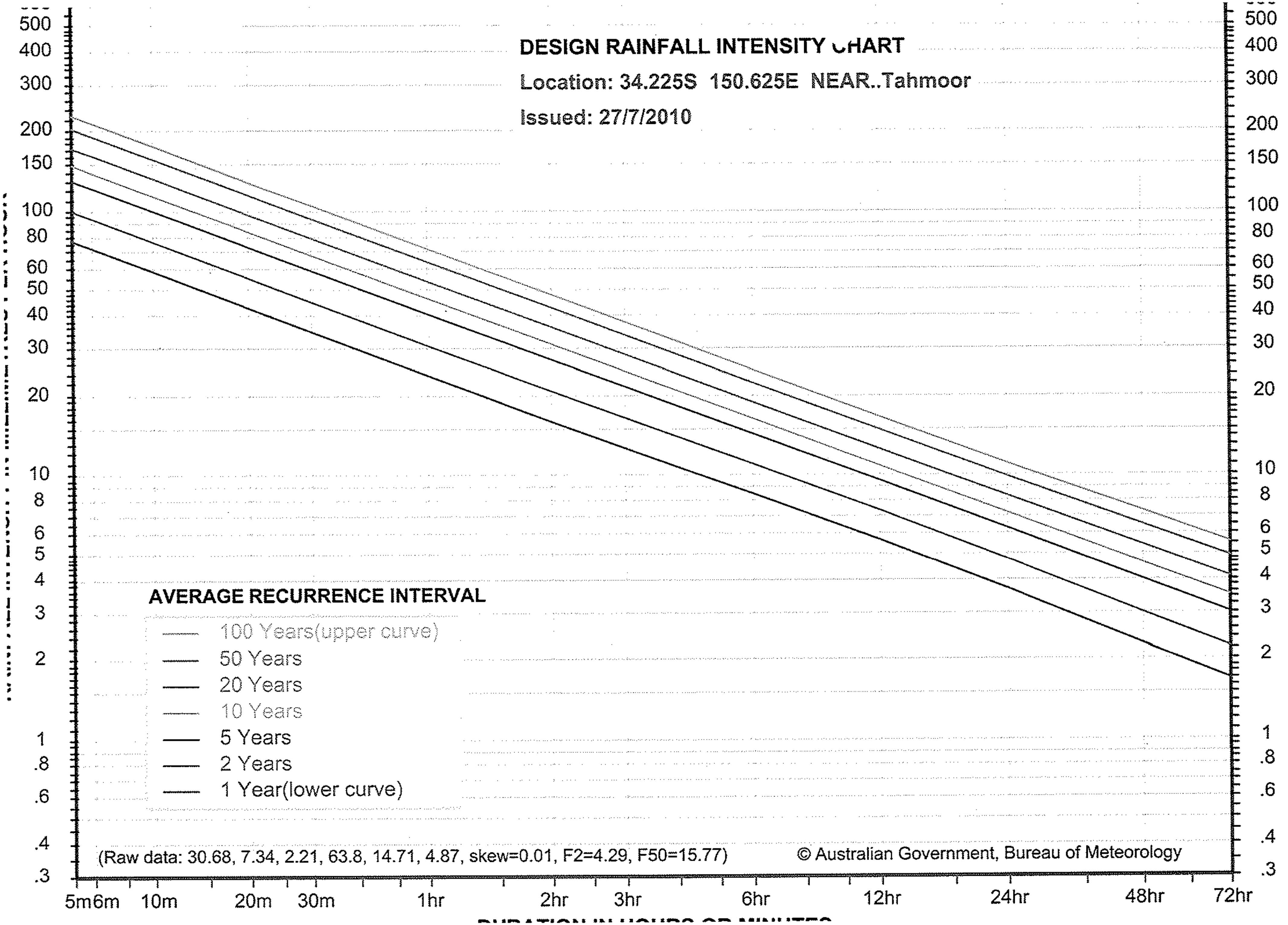


Appendix D - Rainfall Intensity-Frequency-Duration Data



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AVERAGE RECURRENCE INTERVAL
100 Years(upper curve)
50 Years
20 Years
10 Years
5 Years
2 Years
1 Year(lower curve)
(Raw data: 30.68, 7.34, 2.21, 63.8, 14.71, 4.87, skew=0.01, F2=4.29, F50=15.77)
© Australian Government, Bureau of Meteorology
5m6m
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24hr
48hr
72hr

Intensity-Frequency-Duration Table

Location: 34.225S 150.625E NEAR.. Tahmoor Issued: 27/7/2010

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	**1 YEAR**	**2 YEARS**	**5 YEARS**	**10 YEARS**	**20 YEARS**	**50 YEARS**	**100 YEARS**
5Mins	76.8	99.6	130	149	172	204	228
6Mins	72.0	93.3	122	139	162	191	214
10Mins	58.9	76.3	100	114	133	157	176
20Mins	42.7	55.5	72.9	83.3	96.7	115	128
30Mins	34.7	45.0	59.3	67.8	78.8	93.4	105
1Hr	23.7	30.7	40.5	46.4	53.9	64.0	71.7
2Hrs	15.9	20.7	27.2	31.1	36.1	42.8	47.9
3Hrs	12.6	16.4	21.5	24.5	28.4	33.6	37.6
6Hrs	8.48	11.0	14.3	16.3	18.8	22.2	24.8
12Hrs	5.64	7.31	9.52	10.8	12.5	14.8	16.5
24Hrs	3.66	4.75	6.25	7.14	8.30	9.84	11.0
48Hrs	2.27	2.97	3.98	4.59	5.38	6.43	7.25
72Hrs	1.68	2.21	2.98	3.46	4.07	4.88	5.51

Raw data: 30.68, 7.34, 2.21, 63.8, 14.71, 4.87, skew=0.01, F2=4.29, F50=15.77)

Polynomial Coefficients Table

Location: 34.225S 150.625E NEAR.. Tahmoor Issued: 27/7/2010

List of coefficients to equations of the form

$$\log_e(I) = A + B \times (\log_e(T)) + C \times (\log_e(T))^2 + D \times (\log_e(T))^3 + E \times (\log_e(T))^4 + F \times (\log_e(T))^5 + G \times (\log_e(T))^6$$

T = Time in hours and I = Intensity in millimetres per hour

EARS	A	B	C	D	E	F	G
	3.1636900902	-5.6455338E-1	-1.3287317E-2	8.5687432E-3	-1.5987686E-3	-3.5698334E-4	6.3636995E-5
	3.4256930351	-5.6510568E-1	-1.4766109E-2	8.6155711E-3	-1.4153159E-3	-3.5901766E-4	6.0270031E-5
	3.7018125057	-5.6585443E-1	-1.9042967E-2	7.9358211E-3	-7.5345510E-4	-2.5756375E-4	2.6020007E-5
0	3.8363180161	-5.6618804E-1	-2.1450911E-2	7.6758265E-3	-3.9755230E-4	-2.2354297E-4	1.1706716E-5
0	3.9877319336	-5.6600356E-1	-2.3422411E-2	7.1022497E-3	-6.6705400E-5	-1.4922861E-4	-8.8504630E-6
0	4.1587071419	-5.6644535E-1	-2.5627440E-2	6.8096416E-3	2.7788000E-4	-1.0151308E-4	-2.6598349E-5
00	4.272837162	-5.6690347E-1	-2.7182834E-2	6.6674487E-3	5.0829420E-4	-7.5548330E-5	-3.7241898E-5

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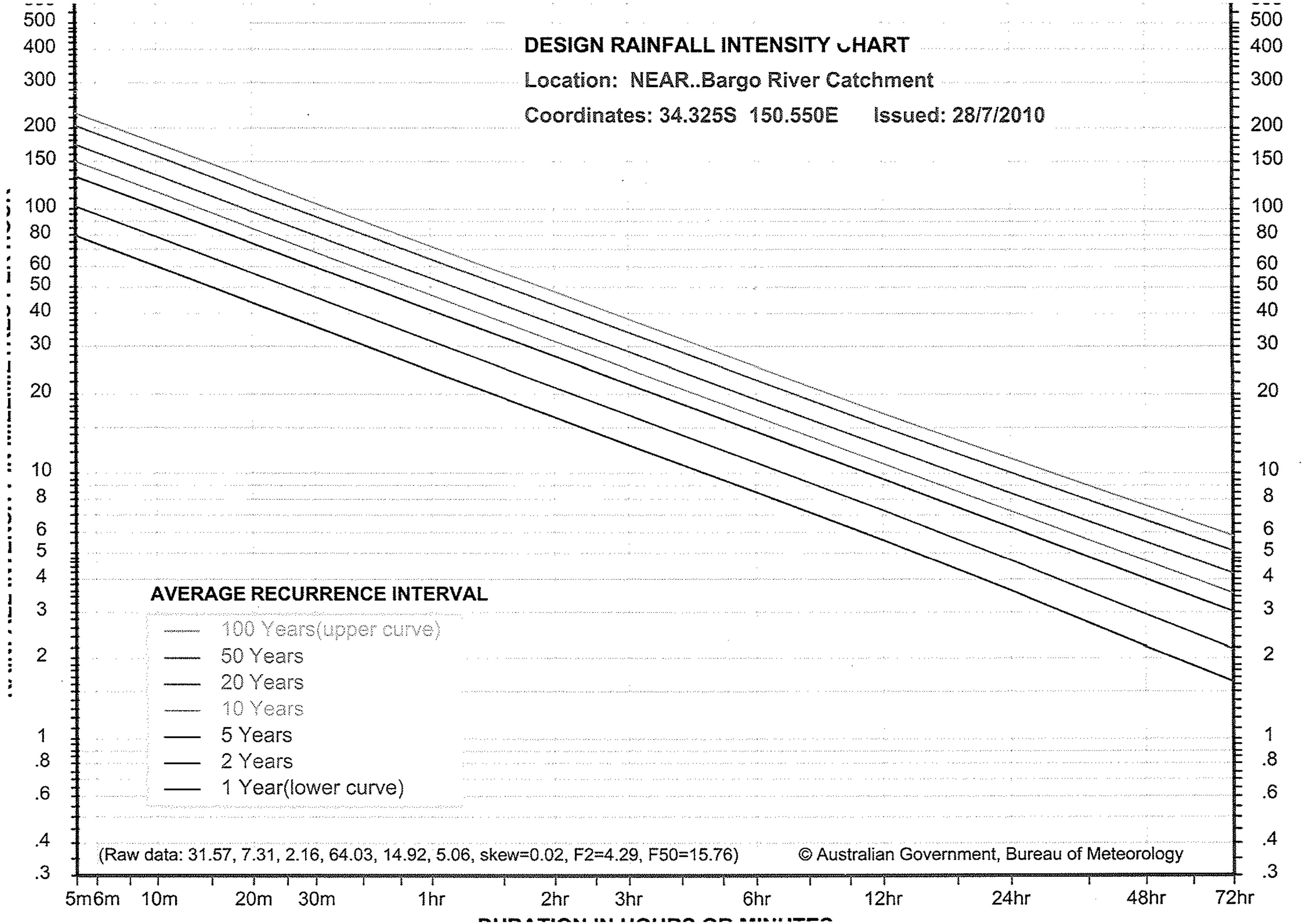
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100 Years(upper curve)
50 Years
20 Years
10 Years
5 Years
2 Years
1 Year(lower curve)
(Raw data: 31.57, 7.31, 2.16, 64.03, 14.92, 5.06, skew=0.02, F2=4.29, F50=15.76)
© Australian Government, Bureau of Meteorology
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48hr
72hr

Intensity-Frequency-Duration Table

Location: 34.325S 150.550E NEAR.. Bargo River Catchment Issued: 28/7/2010

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	79.0	102	132	150	174	205	228
6Mins	73.9	95.6	124	141	163	192	214
10Mins	60.5	78.3	102	116	134	158	176
20Mins	44.0	57.0	74.1	84.3	97.5	115	129
30Mins	35.8	46.3	60.3	68.6	79.5	93.8	105
1Hr	24.3	31.5	41.2	47.0	54.5	64.4	72.0
2Hrs	16.3	21.1	27.6	31.4	36.5	43.1	48.3
3Hrs	12.8	16.6	21.7	24.7	28.7	33.9	38.0
6Hrs	8.51	11.0	14.4	16.4	19.0	22.5	25.2
12Hrs	5.60	7.27	9.55	10.9	12.7	15.0	16.8
24Hrs	3.60	4.69	6.26	7.22	8.44	10.1	11.4
48Hrs	2.21	2.92	3.99	4.66	5.51	6.66	7.56
72Hrs	1.63	2.16	2.99	3.51	4.18	5.09	5.80

Raw data: 31.57, 7.31, 2.16, 64.03, 14.92, 5.06, skew=0.02, F2=4.29, F50=15.76)

Polynomial Coefficients Table

Location: 34.325S 150.550E NEAR.. Bargo River Catchment Issued: 28/7/2010

List of coefficients to equations of the form

$$\log_e(I) = A + B \times (\log_e(T)) + C \times (\log_e(T))^2 + D \times (\log_e(T))^3 + E \times (\log_e(T))^4 + F \times (\log_e(T))^5 + G \times (\log_e(T))^6$$

T = Time in hours and I = Intensity in millimetres per hour

'EARS	A	B	C	D	E	F	G
	3.192337513	-5.7254189E-1	-1.8826658E-2	9.3430048E-3	-1.2260013E-3	-4.6475921E-4	7.0950970E-5
	3.4513559341	-5.7137567E-1	-1.9107351E-2	8.9341244E-3	-1.1108463E-3	-4.0364123E-4	5.9224272E-5
	3.7188010216	-5.6798887E-1	-2.1586100E-2	7.8758504E-3	-4.9716290E-4	-2.5375356E-4	1.8703851E-5
0	3.8496251106	-5.6641918E-1	-2.3173837E-2	7.4104420E-3	-1.4015000E-4	-1.8755867E-4	-1.8390170E-6
0	3.9976949692	-5.6470573E-1	-2.4032341E-2	6.8689282E-3	9.4700900E-5	-1.1588413E-4	-1.8929040E-5
0	4.1651363373	-5.6358331E-1	-2.5140455E-2	6.5823426E-3	3.4573880E-4	-6.4830600E-5	-3.3555138E-5
00	4.276948452	-5.6269044E-1	-2.5812751E-2	6.3335197E-3	5.0432490E-4	-2.5936890E-5	-4.3721357E-5

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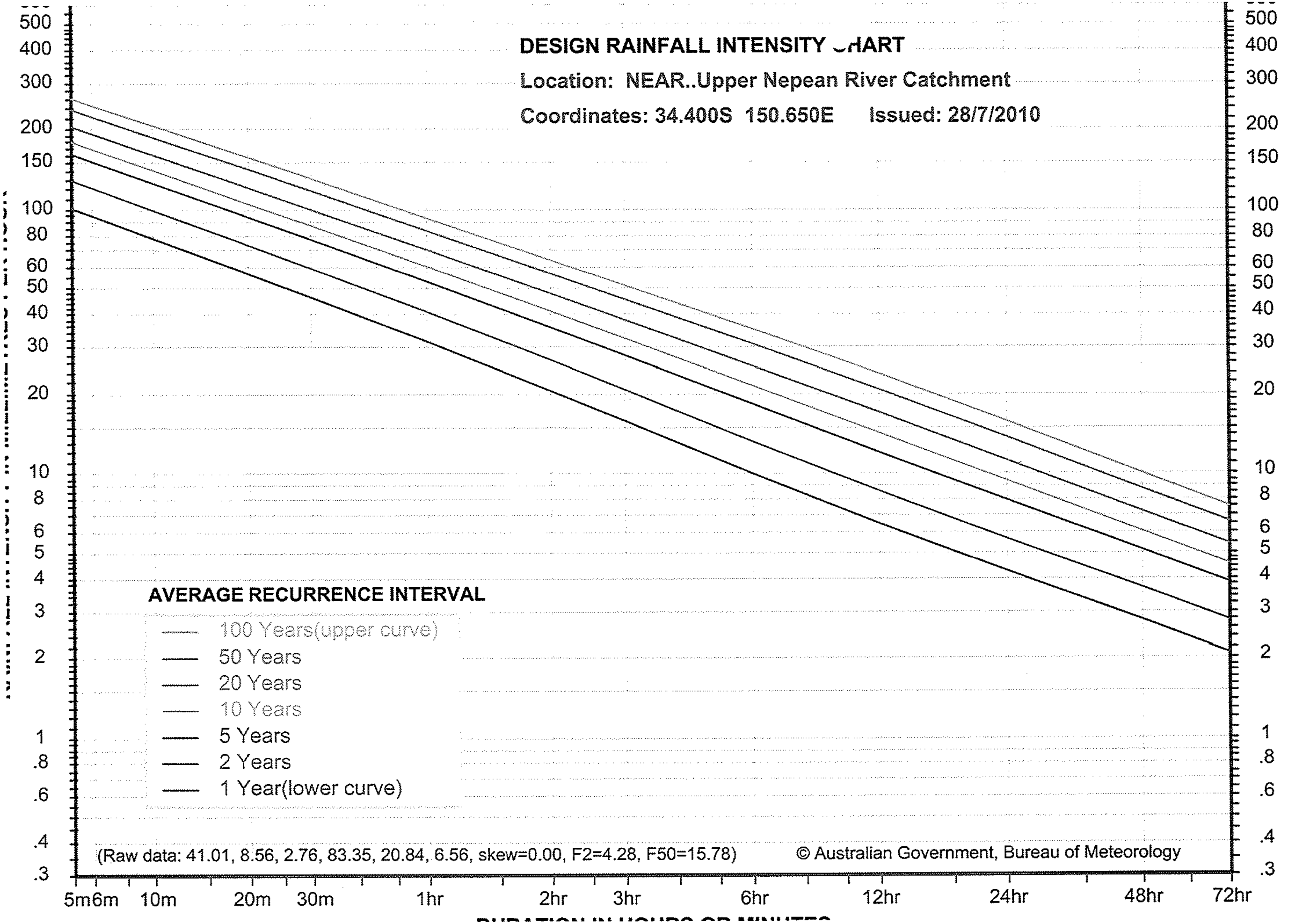

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AVERAGE RECURRENCE INTERVAL
100 Years(upper curve)
50 Years
20 Years
10 Years
5 Years
2 Years
1 Year(lower curve)
(Raw data: 41.01, 8.56, 2.76, 83.35, 20.84, 6.56, skew=0.00, F2=4.28, F50=15.78)
© Australian Government, Bureau of Meteorology
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5m 6m 10m 20m 30m 1hr 2hr 3hr 6hr 12hr 24hr 48hr 72hr

Intensity-Frequency-Duration Table

Location: 34.400S 150.650E NEAR.. Upper Nepean River Catchment Issued: 28/7/2010

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	**1 YEAR**	**2 YEARS**	**5 YEARS**	**10 YEARS**	**20 YEARS**	**50 YEARS**	**100 YEARS**
5Mins	101	129	162	180	205	238	262
6Mins	94.8	121	152	169	193	224	246
10Mins	77.7	99.4	126	141	161	187	207
20Mins	57.0	73.2	93.7	105	121	142	157
30Mins	46.4	59.8	77.1	87.1	100	118	131
1Hr	31.5	40.8	53.3	60.7	70.3	83.0	92.6
2Hrs	20.5	26.8	35.6	41.0	47.9	57.0	64.1
3Hrs	15.8	20.7	27.9	32.3	38.0	45.5	51.3
6Hrs	10.0	13.2	18.3	21.4	25.4	30.8	35.0
12Hrs	6.45	8.58	12.0	14.2	17.0	20.7	23.7
24Hrs	4.24	5.64	7.93	9.38	11.2	13.7	15.7
48Hrs	2.77	3.67	5.12	6.02	7.18	8.74	10.0
72Hrs	2.08	2.76	3.84	4.52	5.39	6.56	7.48

(Raw data: 41.01, 8.56, 2.76, 83.35, 20.84, 6.56, skew=0.00, F2=4.28, F50=15.78)

Polynomial Coefficients Table

Location: 34.400S 150.650E NEAR.. Upper Nepean River Catchment Issued: 28/7/2010

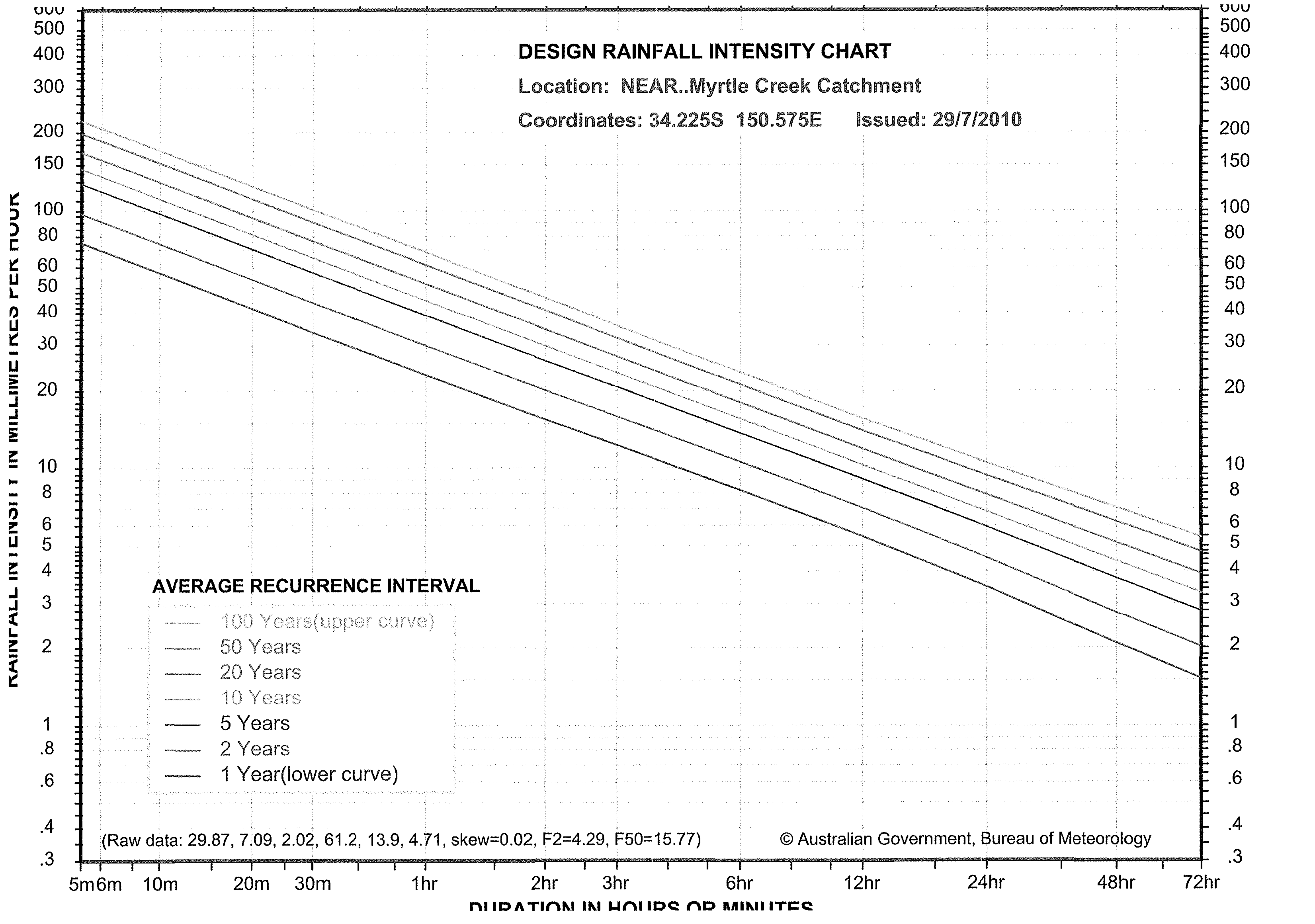
List of coefficients to equations of the form

$$\log_e(I) = A + B \times (\log_e(T)) + C \times (\log_e(T))^2 + D \times (\log_e(T))^3 + E \times (\log_e(T))^4 + F \times (\log_e(T))^5 + G \times (\log_e(T))^6$$

T = Time in hours and I = Intensity in millimetres per hour

'EARS	A	B	C	D	E	F	G
	3.4499716759	-5.9260005E-1	-4.3542635E-2	6.9029992E-3	2.0406758E-3	-1.0238702E-4	-7.5819262E-5
	3.7087404728	-5.8404946E-1	-4.1329328E-2	7.2600092E-3	1.6963753E-3	-1.6729940E-4	-5.5072698E-5
	3.9758548737	-5.6007504E-1	-3.5503849E-2	7.6905736E-3	9.0531560E-4	-2.7469365E-4	-1.5875237E-5
0	4.1054606438	-5.4782158E-1	-3.2572050E-2	8.0765281E-3	4.6981930E-4	-3.5032327E-4	8.8216710E-6
0	4.2525644302	-5.3771853E-1	-2.9875269E-2	8.3713029E-3	7.8199600E-5	-4.0659634E-4	2.9265148E-5
0	4.4185166359	-5.2639753E-1	-2.7277166E-2	8.7715276E-3	-2.9737770E-4	-4.8333421E-4	5.1852741E-5
00	4.5287661552	-5.1889008E-1	-2.5206460E-2	8.9840833E-3	-6.0126180E-4	-5.2290730E-4	6.7123117E-5

'aw data: 41.01, 8.56, 2.76, 83.35, 20.84, 6.56, skew=0.00, F2=4.28, F50=15.78)


DESIGN RAINFALL INTENSITY CHART
Location: NEAR..Myrtle Creek Catchment
Coordinates: 34.225S 150.575E Issued: 29/7/2010
AVERAGE RECURRENCE INTERVAL
100 Years(upper curve)
50 Years
20 Years
10 Years
5 Years
2 Years
1 Year(lower curve)
(Raw data: 29.87, 7.09, 2.02, 61.2, 13.9, 4.71, skew=0.02, F2=4.29, F50=15.77)
© Australian Government, Bureau of Meteorology
RAINFALL INTENSITY IN MILLIMETRES PER HOUR
DURATION IN HOURS OR MINUTES
5m 6m 10m 20m 30m 1hr 2hr 3hr 6hr 12hr 24hr 48hr 72hr
600 500 400 300 200 150 100 80 60 50 40 30 20 10 8 6 5 4 3 2 1 .8 .6 .4 .3

Intensity-Frequency-Duration Table

Location: 34.225S 150.575E NEAR.. Myrtle Creek Catchment Issued: 29/7/2010

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	75.0	97.2	127	145	168	199	223
6Mins	70.2	91.0	119	136	158	187	209
10Mins	57.4	74.4	97.6	111	129	153	171
20Mins	41.7	54.1	70.9	80.8	93.9	111	124
30Mins	33.8	43.9	57.5	65.6	76.2	90.2	101
1Hr	23.0	29.9	39.2	44.7	52.0	61.6	68.9
2Hrs	15.5	20.1	26.2	29.9	34.7	41.0	45.8
3Hrs	12.3	15.9	20.7	23.5	27.2	32.1	35.8
6Hrs	8.24	10.6	13.7	15.6	18.0	21.1	23.5
12Hrs	5.44	7.03	9.10	10.3	11.9	14.0	15.6
24Hrs	3.47	4.50	5.93	6.79	7.90	9.39	10.5
48Hrs	2.09	2.75	3.74	4.36	5.14	6.21	7.03
72Hrs	1.52	2.02	2.79	3.28	3.89	4.73	5.39

Raw data: 29.87, 7.09, 2.02, 61.2, 13.9, 4.71, skew=0.02, F2=4.29, F50=15.77)

Polynomial Coefficients Table

Location: 34.225S 150.575E NEAR.. Myrtle Creek Catchment Issued: 29/7/2010

List of coefficients to equations of the form

$$\log_e(I) = A + B \times (\log_e(T)) + C \times (\log_e(T))^2 + D \times (\log_e(T))^3 + E \times (\log_e(T))^4 + F \times (\log_e(T))^5 + G \times (\log_e(T))^6$$

T = Time in hours and I = Intensity in millimetres per hour

YEARS	A	B	C	D	E	F	G
1	3.1363518238	-5.6660241E-1	-1.2059141E-2	9.2933951E-3	-2.0635619E-3	-4.8542290E-4	9.5817639E-5
2	3.3972444534	-5.6843907E-1	-1.3849086E-2	9.5391544E-3	-1.8301957E-3	-4.9395498E-4	9.2177863E-5
5	3.6691231728	-5.7029587E-1	-1.9078700E-2	8.2020322E-3	-8.3805730E-4	-2.9501141E-4	3.3675104E-5
10	3.8010032177	-5.7152784E-1	-2.1568250E-2	7.7472208E-3	-3.8078460E-4	-2.1894070E-4	1.0024268E-5
20	3.9509887695	-5.7190543E-1	-2.3727784E-2	6.8491008E-3	7.2241100E-5	-9.3676190E-5	-2.2655375E-5
50	4.120036602	-5.7277435E-1	-2.6263909E-2	6.1832322E-3	5.6953790E-4	7.7786600E-6	-5.2467949E-5
100	4.2332692146	-5.7359427E-1	-2.7922625E-2	5.8876923E-3	8.6139470E-4	5.6596510E-5	-6.7797962E-5

Raw data: 29.87, 7.09, 2.02, 61.2, 13.9, 4.71, skew=0.02, F2=4.29, F50=15.77)

Appendix E - Rational Method Calculations

TABLE E: Rational Method Calculations for the 100 Year ARI Event

Catchment	Area (km2)	t_c (hrs)	$It_{c,100}$ (mm/hr)	C_{10}	$I_{12,2}$ (mm/hr)	$I_{12,50}$ (mm/hr)	FF_{100}	C_{100}	Q_{100} (m^3/s)
Mrytle Creek	9.56	1.8	50	0.47	7.00	14.00	1.39	0.66	86.2
Watercourse 2	0.33	0.5	108	0.48	7.40	15.00	1.38	0.66	6.6
Bargo River	141	5.0	29	0.57	7.40	15.00	1.38	0.79	877.5
Upper Nepean River	705	9.2	28	0.90	8.60	21.00	1.13	1.02	5601.7
Bargo & Upper Nepean Rivers	846	-	-	-	-	-	-	-	6479.2

Time of Concentration $t_c = 0.76A^{0.38}$

Design Rainfall Intensities $I_{t_c,100}, I_{12,50}, I_{12,2}$

10 Year ARI Runoff Coefficient C_{10}

100 Year ARI Runoff Coefficient $C_{100} = C_{10} \times FF_{100} = C_{10} \times \left(2.57 - \frac{0.588 I_{12,50}}{I_{12,2}}\right)$

Design Peak Discharge $Q_{100} = 0.278 C_{100} I_{t_c,100} A$

FIGURE 1

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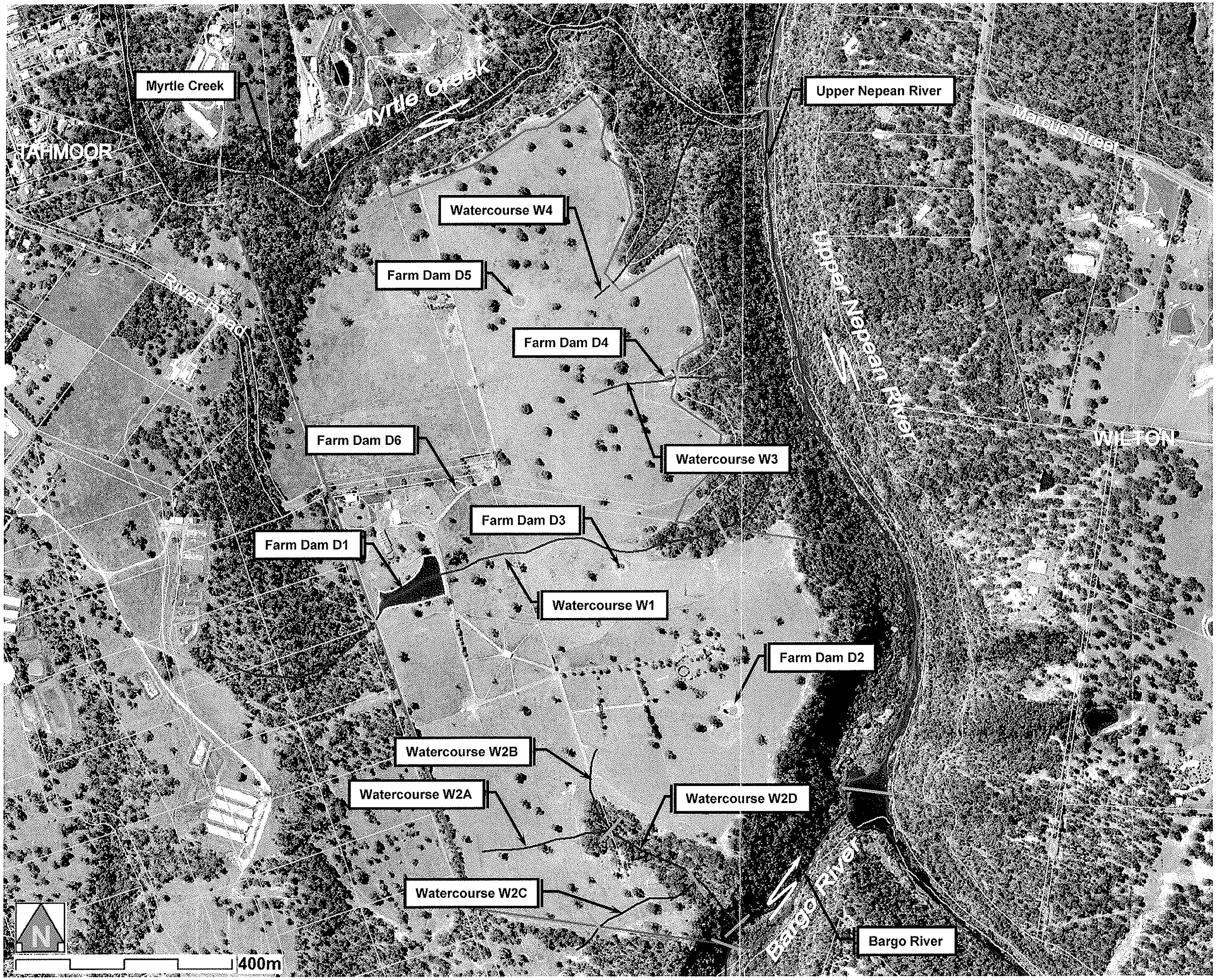
rp301015-02294 165 – 185 River Road Stream Classification and SFA
fg301015-02294-100813_Fig1 Site Boundary.doc

EXTENT OF SITE AT 165 – 185 RIVER ROAD, TAHMOOR

FIGURE 2



LEGEND

Site Boundary

Farm Dam

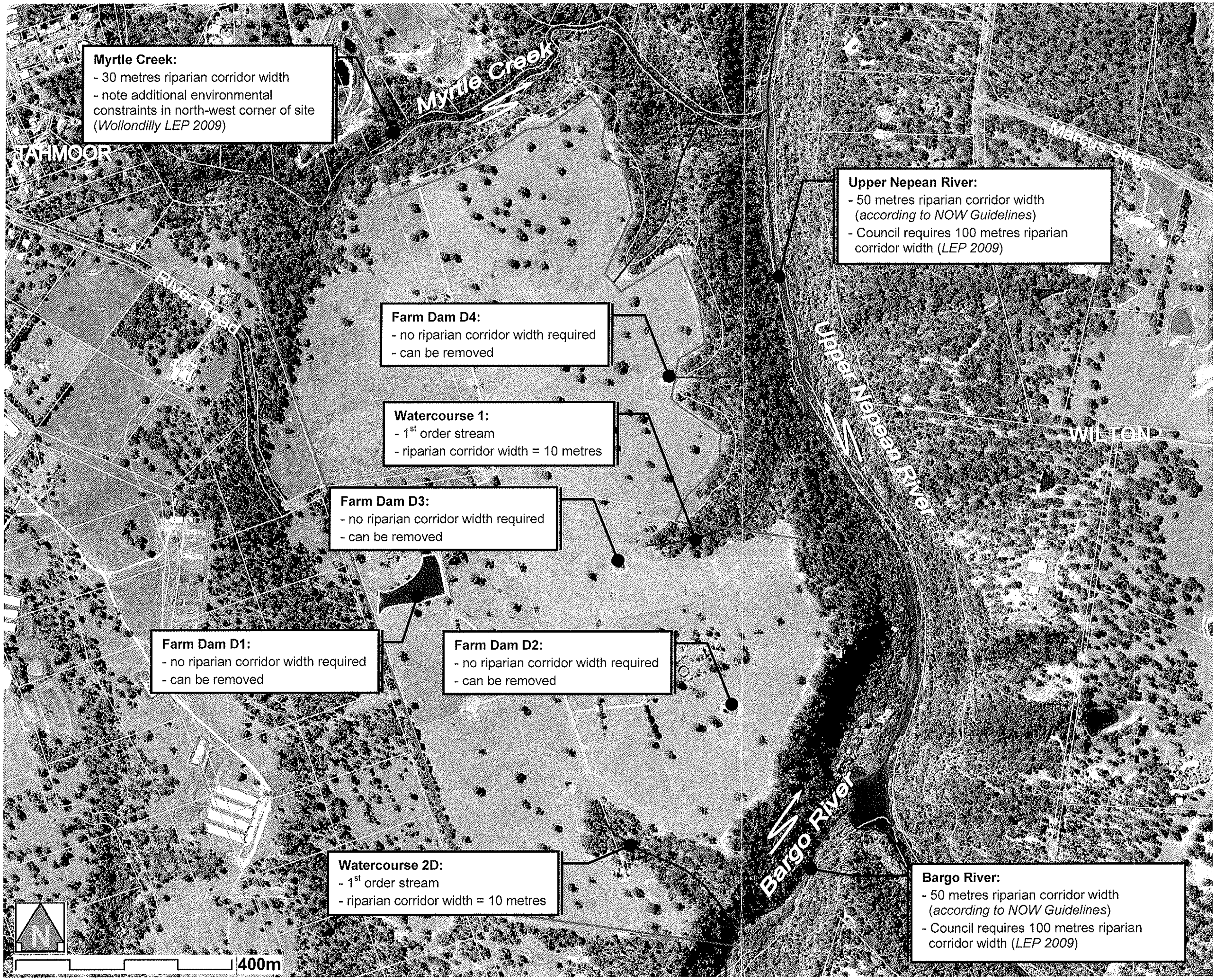
Watercourse

Extents of watercourse assessments

WorleyParsons
resources & energy

rp301015-02294 165 – 185 River Road Stream Classification and SFA
fg301015-02294-100813_Fig2 LPMA Watercourses.doc

WATERCOURSES AND FARM DAMS SHOWN IN AVAILABLE MAPPING AND AERIAL PHOTOGRAPHY



LEGEND

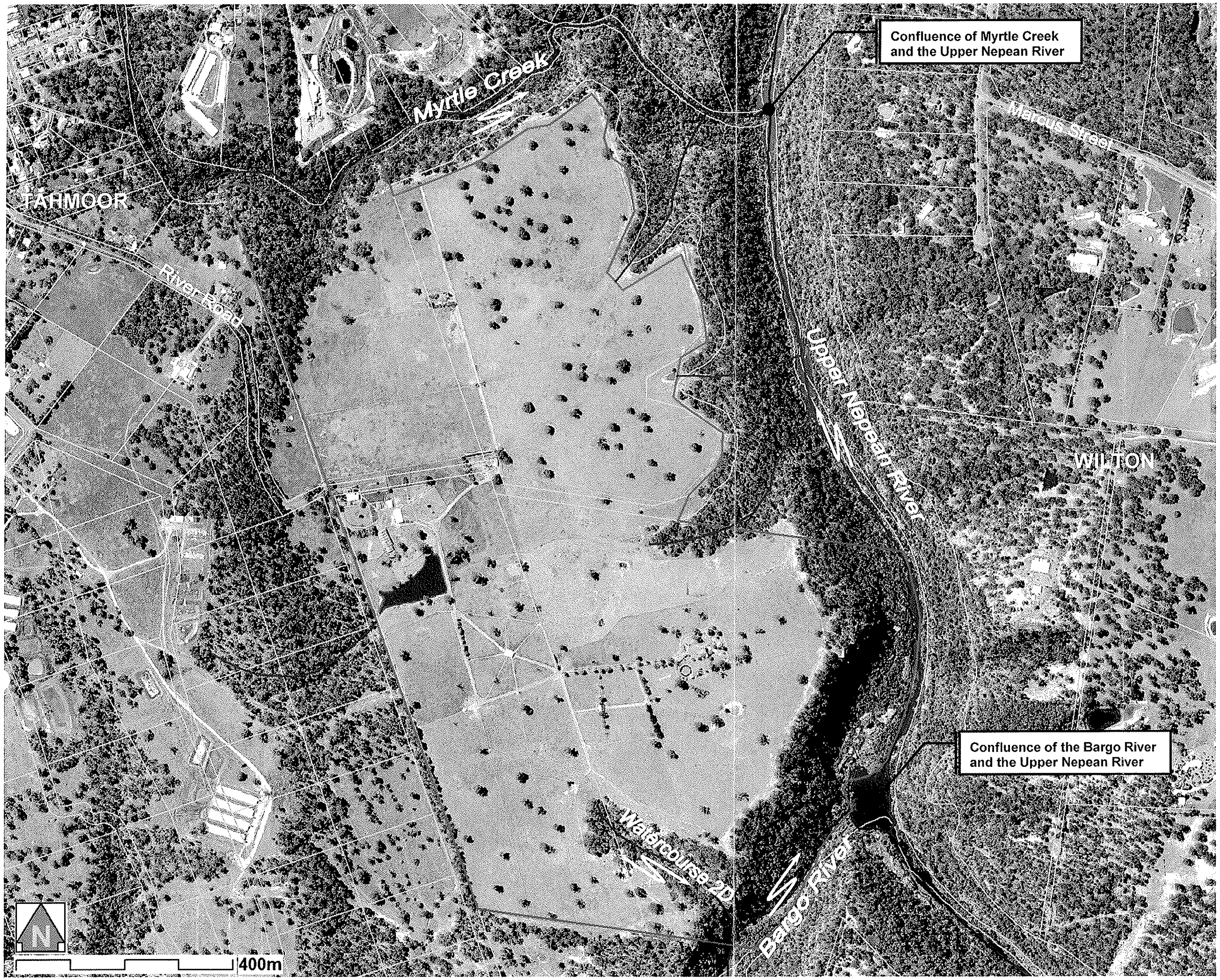
Site Boundary

WorleyParsons
resources & energy

rp301015-02294 165 – 185 River Road Stream Classification and SFA
fg301015-02294-100813_Fig3 Recommended Corridor Widths.doc

RECOMMENDED RIPARIAN CORRIDOR WIDTHS

FIGURE 4



LEGEND

Site Boundary

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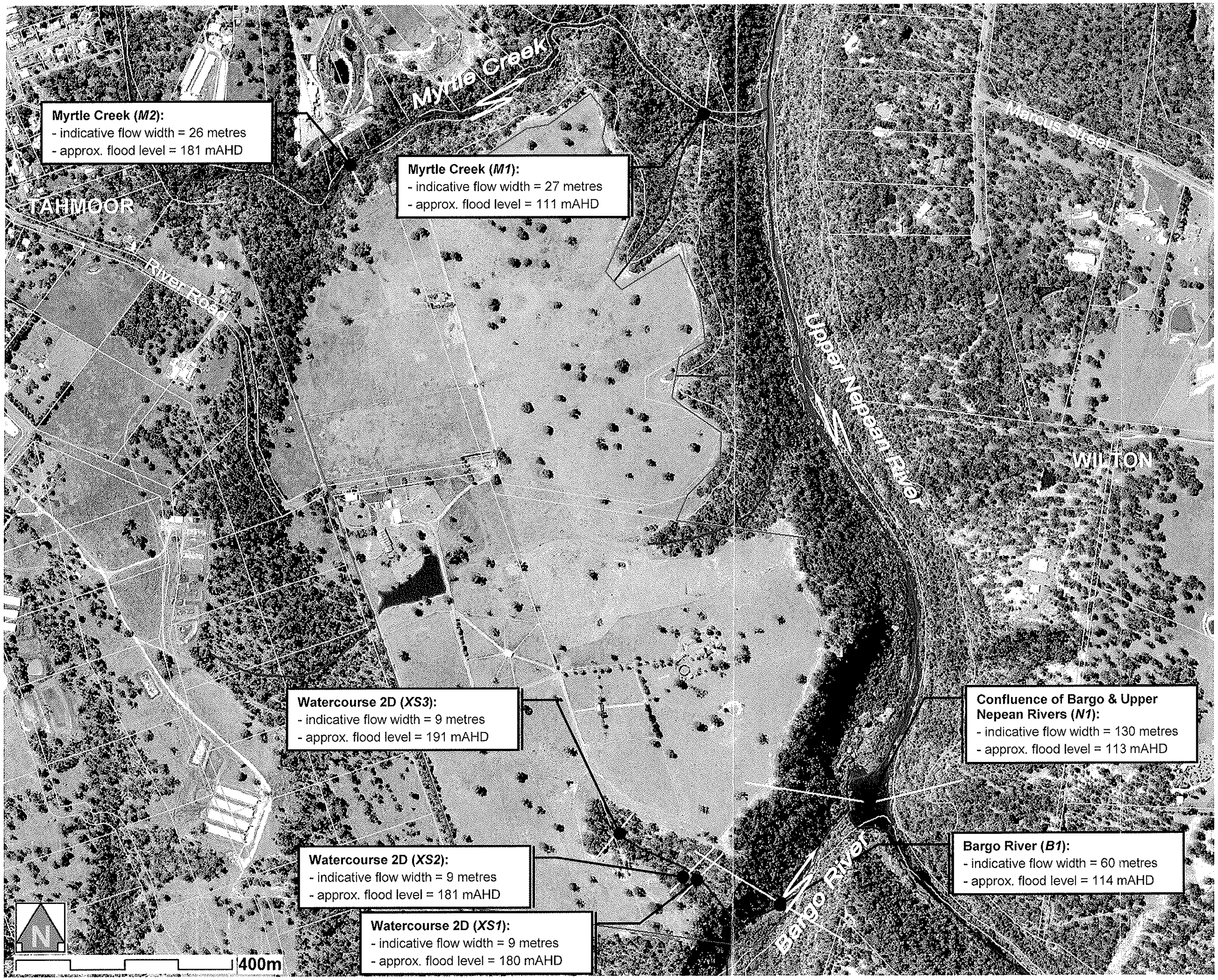
301015-00000 – 165-185 River Road Stream Classification and SFA
fg301015-02294-100802_Fig4 Site Waterways.doc

WATERWAYS ASSESSED AS PART OF THE SITE FLOOD ASSESSMENT FOR 165 – 185 RIVER ROAD, TAHMOOR



LEGEND

Site Boundary

Watercourse Cross-section for Hydraulic Analyses

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301015-00000 – 165-185 River Road Stream Classification and SFA
fg301015-02294-100813_Fig5 Hydraulic Analyses X-Sections.doc

FLOOD CHARACTERISTICS AT 165 – 185 RIVER ROAD, TAHMOOR