CESSNOCK

DEVELOPMENT CONTROL PLAN

PART E – SPECIFIC AREAS

E.11: NORTH BELLBIRD PRECINCT

Amendment History

Version No.	Nature of Amendment	Date in force
1	Initial adoption by Council on 5 August 2009	28 January 2011
2	Consequential amendments as a result of Cessnock Local Environmental Plan	23 December 2011

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APPENDIX 4: Floodplain Risk Management and Stormwater Management Strategy – Patterson Britton & Partners Pty Ltd, dated August 2007.
APPENDIX 5: North Bellbird Rezoning – Stormwater and Floodplain Management Report - Worley Parsons, dated 29 October 2008.

E . 1 1 NORTH BELLBIRD PRECINCT

1 1 . 1 INTRODUCTION

This document is called the North Bellbird Precinct Plan, and forms part of the Cessnock Development Control Plan 2010.

11.1.1. Application

This chapter applies to land in the North Bellbird Precinct as illustrated in **Figure 1**. This chapter consists of written statements, maps and appendices.

11.1.2 Purpose

This Chapter adds detail to those planning provisions contained in Cessnock Local Environmental Plan. The plan provides detailed guidelines for the development of land within the area to which the plan applies for the purpose of land subdivision so as to facilitate the erection of dwelling houses or other buildings, including supporting infrastructure and community related uses. The plan also provides a basis upon which to implement stated objectives for the North Bellbird Precinct.

11.1.3 Objectives

a) to designate appropriate areas for development and conservation;
b) to provide accessible neighbourhoods with an interconnected network of streets which provides safe, direct access to public transport;
c) To facilitate appropriate mixed use development which is compatible with residential amenity, capable of adapting over time as the community changes, and which reflects community standards of health, safety and amenity;
d) To provide a variety of lot sizes and housing types to cater for the diverse housing needs of the community at a density that can ultimately support the provision of local services;
e) To provide for appropriate development of the land having regard to general flooding considerations and the need for specific development controls catering for development affected by the Probable Maximum Flood (PMF) event;
f) to protect areas of significant vegetation and to enhance the habitat of threatened species and promote biodiversity;
g) to protect the water quality of receiving streams and to reduce land degradation; and
h) to reduce the potential for land use conflict between the development arising as a result of the subdivision of the land and neighbouring viticultural and non-viticultural rural land uses by ensuring sympathetic location and design of new subdivisions.

11.1.4 Requirements of State Government Authorities

All relevant State Government Authorities were consulted during the preparation of this plan. Any recommendations made have been considered and, where possible, incorporated into the plan. Applicants are advised to contact the relevant authorities during the preparation of a development application.

Applicants are to have particular regard to the Part 6 – Urban release Areas of the Cessnock Local Environment Plan which provides for State Infrastructure levies and/or requirements.

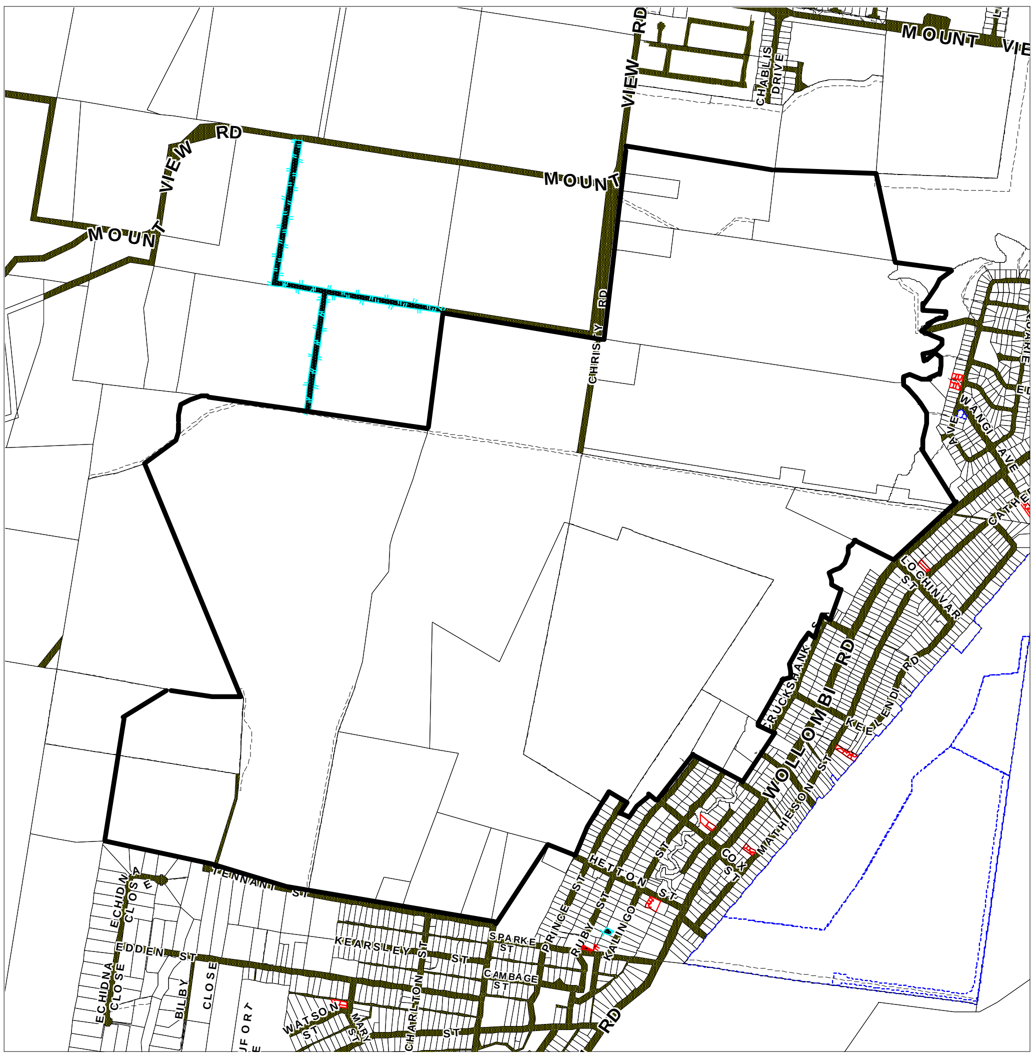
11.1.5 Definitions

“public place” includes any park or garden, playing field or any place to which the public have or are permitted to have access, but excludes roads and travelling stock reserves.

“separation distance” means a measure of land within which no public place, dwelling-house or commercial vineyard (as relevant) is located.

“vegetation chemical spray drift buffer” means a specified area of vegetation planting, with the primary purpose of intercepting and collecting chemical spray drift (see **Appendix 3** for specifications).

Figure 1 – Locality Plan



11.2 GENERAL DEVELOPMENT CONSIDERATIONS AND DEVELOPMENT APPLICATION REQUIREMENTS

The following development considerations apply to all land subdivisions within the area to which this plan applies.

11.2.1 Potentially Contaminated Land

Objectives

- To ensure that built development is not sited or operated on contaminated land so that humans are not subject to potential impacts associated with such contamination.

Requirements

- Submission of details outlining the history of land uses on the land to initially determine if the land is likely to be contaminated.
- In cases where the land is likely to be contaminated the Council may require submission of a report from a suitably qualified professional clearly specifying the extent of contamination from past viticultural, agricultural or other activities, and the measures proposed to decontaminate that land.

11.2.2 Clearing of Vegetation

Objectives

- In accordance with the objectives of minimising land degradation, enhancing the water quality characteristics of the North Bellbird Precinct and actively fostering the promotion of biodiversity and ecological sustainability, ensuring that only limited amounts of remaining vegetation are cleared in the Precinct adjoining riparian areas and on flood prone land.
- To actively foster the principle of 'no net loss of vegetation' within the North Bellbird Precinct.
- To draw people's attention to the requirements for development consent for clearing of vegetation in the North Bellbird Precinct.

Requirements

- Council will not support the clearing of native trees and shrubs in areas designated as native vegetation corridor in **Appendix 1**.
- Council supports the re-establishment of vegetation within the specified native vegetation corridors and encourages appropriate plantings in those open space areas that adjoin the Vineyard District prior to development occurring in these areas.
- Plant species should be selected from those contained within **Appendices 2** and **3** as relevant and as specified. Council will require the continued maintenance of this vegetation, eg. through consent conditions, and where significant amounts of native vegetation are concerned, through instruments attached to the life of the property. A refundable bond may also be required over a specified time frame.
- In the case of development consents involving the revegetation of native vegetation corridors, Council will require the establishment of the required native vegetation and any associated fencing to be constructed prior to the issue of a subdivision certificate for the development.
- Council may require that information from a qualified person detailing the impact of proposed clearing on the habitat and biodiversity characteristics of the site be provided, including the potential for its impact on endangered and threatened species (for details see Section 11.2.3 below).

11.2.3 Flora and Fauna Considerations

The Environmental Planning and Assessment Act, 1979 (as amended), and the Threatened Species Conservation Act, 1995 require Council to give consideration to the likely impact of a development on the flora and fauna characteristics of a particular site and its locality.

Where clearing is proposed, or farm dams are proposed to be filled, Council will require the preparation of a flora/fauna assessment in accordance with the requirements of current legislation. A subsequent Species Impact Statement may also be required. Please check with Council's Development Assessment Planners to determine Council's requirements in this regard.

Objectives

- To foster and actively encourage the concepts of ecological sustainability and enhanced biodiversity through requirements for the continued existence of native flora and fauna in the North Bellbird Precinct, including threatened species.

Requirements

- Check with Council's Development Assessment Planners to determine requirements for preparation of a preliminary flora/fauna assessment and Species Impact Statements.

Source: Strahan, 1995

Source: Roach, 1998

11.2.4 Aboriginal Archaeology and European Heritage

Objectives

- To recognise and conserve the aboriginal archaeology of the North Bellbird Precinct.

Aboriginal Archaeology

An Aboriginal site is any place which has the remains of prehistoric and historic occupation, or is of contemporary significance to the Aboriginal community. The most common sites known are ***Open Stone Artefact Scatters***.

Open sites usually consist of scatters of stone artefacts found in the open. They are places where people lived and contain evidence of Aboriginal activities such as the manufacture of stone tools. Rarer features such as earth ovens, stone hearths and heat treatment pits also reveal evidence of a range of activities such as the preparation and cooking of food.

Open sites can be found on riverbanks, plains, hillsides, crests, ridges and saddles. They are usually situated in a level position near fresh water. Some sites may be difficult to detect as they can be large and scattered and may also be buried by deposits which can reach a metre or so in depth. They may also be obscured by leaf litter or have vegetation growing over the site.

These sites are significant to Aboriginal people because they are evidence of past Aboriginal occupation of Australia, and are valued as a link with their traditional culture. They are also of scientific significance providing information about stone technology. Undisturbed open sites can be excavated to reveal hearths containing charcoal which can be used to date commencement of Aboriginal occupation of a site.

All Aboriginal relics are protected under the National Parks and Wildlife Act 1974, and as such may not be interfered with, defaced, damaged or destroyed without the written consent of the Director of the Department of Environment and Climate Change (DECC). If a site is discovered it must be reported immediately to the Director of the DECC.

Requirements

- Investigate the Aboriginal qualities of your site and the likely impact of your proposed subdivision on items of such heritage. A qualified archaeologist may be required to carry out investigations in areas of likely impact. Please discuss the need for such investigation with Council's Development Assessment Planners.
- Investigate the European heritage qualities of your site and the likely impact of your proposal on items of heritage. A qualified heritage practitioner may be required to carry out investigations in areas of likely impact. Please discuss the need for such investigation with Council's Development Assessment Planners.

Note: The Department of Environment and Climate Change can be contacted for a list of qualified consultants regarding sites of Aboriginal Heritage significance or European Heritage.

11.3 STAGING OF DEVELOPMENT

Note: The provisions of this part do not prevent development of land for purposes other than residential development, including rural residential development (ie. mixed use, neighbourhood or community facilities), subject to development consent.

Objectives

To ensure coordinated development of the North Bellbird Release Area over a number of years and the timely provision of adequate social and physical infrastructure. Land within the North Bellbird Release Area will be developed according to a logical and progressive land release program that builds upon existing infrastructure, services, market demand and avoids multiple, fragmented development fronts.

Requirements

- Council may only consider a development application for the subdivision and development of residential land within the North Bellbird Release Area in accordance with the provisions of this plan.
- Council may only consider an application for the subdivision and development of land from the North Bellbird Release Area if it satisfied that:
  - development of the land is consistent with the staging plan at **Appendix 1**; and
  - there is, or satisfactory arrangements have been made for, the delivery of, adequate infrastructure and services to support the development.
- Development of land that is inconsistent with the above provisions can only occur if Council is satisfied that:
  - previously released land has been developed to approximately 75% of its reasonable yield; or
  - there are significant, identifiable constraints on the timely development of land previously released and land identified for release in preceding stages; or
  - the provision of infrastructure before the subdivision of land satisfy the needs that arise from development on the land are available to the land within that stage.
- On aesthetic, social and practicality grounds, development should proceed as either an infill between pockets of existing urban development and/or as a natural extension to existing urban development.
- The initial stages of development should seek to create through-site road link(s) to permit early provision of efficient public bus services, particularly to the neighbourhood centre and community land uses. Initial vehicular access to the site should be direct and have regard for the future development potential of the adjoining and nearby land.
- Employment and community land uses, such as those envisaged for the neighbourhood centre, should be provided concurrent with development of the land to ensure that services are in place to cater for the new population.

11.4 SUBDIVISION DESIGN AND LAYOUT

All development applications for land subdivision are to satisfy the provisions of Part D – Chapter 1 Subdivision Guidelines of this Plan, whilst also having regard to the following specific requirements:

11.4.1 Traffic, Road Design, Pedestrian/Cycleway Networks

Objectives:

- The carrying out of development shall not create or increase ribbon development or adversely affect road safety.
- To provide an efficient street structure to offer a choice of routes and to distribute traffic load through a number of connection points.
- To provide a mix of on road and off road cycle routes.
- To provide appropriate flood free access and creek crossings ie. Bridges.

Requirements:

- The road pattern for the area should be generally developed in accordance with the concepts contained within the North Bellbird Rezoning *Floodplain Risk Management and Stormwater Management Strategy* (**Appendices 4 and 5**).
- Road and access ways within the development site shall be sited and designed to be efficient and practical with regard to expected traffic volumes while minimising any environmental impact.
- Roads layouts, road design, intersections and construction should satisfy the requirements of Council's subdivision guidelines and 'Engineering Requirements for Development.'
- Perimeter Roads (with development on one side only) should be used adjacent to open space, flood prone land and areas of high bushfire risk and visual significance.
- Roads should be designed to provide (where possible) flood free access to proposed allotments.
- Pedestrian paths and cycleways shall be provided within subdivisions to link the community, open space, schools and neighbourhood centre to existing and future residential development.
- Road design and provision of bridges shall have regard to the requirements of the North Bellbird Rezoning *Floodplain Risk Management and Stormwater Management Strategy* (**Appendices 4 and 5**) and all internal construction works shall be at the full cost of the developer.

<u>Temporary Road Access</u>

All allotments must have permanent public road access constructed to Council's standards. Council may, however, permit temporary road access to a land locked parcel where no other public road access is available at the time of approval. This temporary access must be constructed in accordance with Council's requirements with standards depend on the level of traffic generation.

The creation of a temporary road will be in accordance with Section 327 of the Local Government Act 1993.

<u>General Standards:</u>

For subdivisions involving the construction of new roads or access ways, a plan must be developed to illustrate a circulation system which:

(a) relates to the number of lots and expected number of dwellings to be serviced;
(b) minimises impact on the rural landscape and environment through clearing, civil engineering works, or disturbance to natural features;
(c) identifies the role of any access ways in terms of the road hierarchy and the existing grid layout;
(d) employs construction specifications that are sympathetic to the natural site features;
(e) permits flood-free access to each lot; and,
(f) permits pedestrian, equestrian and cycle access with minimal conflict with vehicles.

In determining the standard or road construction reference should be made to Council's "Engineering Requirements for Development" which covers matters of road standards and drainage, and erosion control measures relating to road works.

11.4.2 Lot Configurations

Objectives:

- To ensure that subdivision design, shall provide a mix of lot sizes where possible in order to avoid monotonous layouts and to provide a range of housing opportunities.
- To provide for a safe and accessible neighbourhood that respects the constraints of the site and provides for the communities housing needs.
- To provide a range of public facilities in appropriate locations and in sequence with the land development.
- To ensure that the carrying out of development does not prejudice future urban subdivision in cases where Council is of the opinion that the land has long term urban development potential.

Requirements:

- Development Applications for subdivision must include Staging Plans, an analysis and statement as to the intentions and philosophy of proposed layouts, lot sizes, shapes and likely development densities;
- A variety of lot sizes and shapes are to be provided to cater for the housing needs of the community.
- Lot sizes and dimensions should be in accordance with the requirements set out in Council's Subdivision Guidelines chapter of the City Wide Development Control Plan.
- Subdivision design must have regard to minimising any adverse visual impacts of development when viewed from public roads and surrounding properties.
- Cut and fill should be minimised to fit topography and should absorb the slope on lots within the dwelling footprint rather than on the side boundaries.
- Subdivisions must include conveniently located open space areas that compliment the broader open space networks, in accordance with Council's North Bellbird Section 94 Contributions Plan and **Appendix 1** – Native Vegetation Corridors.

11.4.3 Essential Infrastructure

Objectives:

- To ensure the provision of essential infrastructure to all development in an efficient and economic manner that minimises environmental impacts.

Requirements:

- The provision of energy, communications, water supply, recycled wastewater and sewage management to all development. Evidence that relevant agency approvals and/or satisfactory arrangements have been obtained, shall be provided to Council with Development Applications.

- Satisfactory arrangements (in the opinion of Council) must exist for essential infrastructure and all utility services.
- All new development shall be connected to a reticulated recycled wastewater system where available.
- All services are to be placed underground and are to minimise any environmental, visual and safety impacts

11.4.4 Drainage and Soil and Water Management

Objectives:

- To protect and enhance the water quality, water quantity and habitat value of downstream waterways and environment
- To prevent erosion and run-off during site preparation, construction and the ongoing use of the land to minimise cumulative impact on receiving waterways.
- To identify existing natural trunk drainage paths and manage them according to the requirements of Department of Environment and Climate Change.

Requirements:

- A concept drainage plan, addressing the management of water quality and quantity (having regard to all contributing catchments and downstream water bodies) and relevant flood levels is to be submitted with Development Applications for subdivision. Note: Concept drainage plans shall have regard to the relevant recommendations of the *Floodplain Risk Management and Stormwater Management Strategy* (Patterson Britton & Partners Pty Ltd, August 2007) and *Stormwater and Floodplain Management Report* (Worley Parsons, dated 29 October 2008) as provided by **Appendices 4 and 5.**
- Developers will be required to produce a “Sediment and Erosion Control Plan” as part of the application for subdivision. The plan will also include practical measures for mitigating erosion and controlling sediment during construction. Other detailed plans may be required as a condition of any subdivision approval.
- Existing natural drainage lines should form part of a stormwater and runoff drainage management system utilising soil conservation measures (including detention basins and or wetlands) to alleviate stormwater peaks and retain sediments and pollutants. Any water control structures installed on the site are to be used solely for the purpose of sedimentation and pollution control purposes. No harvesting of water from any watercourse may occur without a license issued by the appropriate government agency.
- Existing major natural drainage lines and watercourses are to be retained wherever possible, and preferably rehabilitated through comprehensive re-planting with indigenous plant species. Major natural drainage lines or proposed new drainage lines located within Native Vegetation Corridors are not be piped and filled.
- Stormwater controls must comply with Council’s "Engineering Requirements for Development".
- The installation of any new water tanks within the North Bellbird Precinct will be equipped with a ‘first flush’ system to enable water to be diverted, reducing the probability of potential contamination of water supply as a result of potential contamination from spray drift.

11.4.5 Flooding

The *Floodplain Risk Management and Stormwater Management Strategy* (Patterson Britton & Partners Pty Ltd, August 2007) assessed the stormwater, flooding and creek rehabilitation constraints for the site and made recommendations and findings relevant to flood and stormwater risk management. These measures are designed to limit the risk to life, property and the environment from the effects of stormwater and flooding.

Objectives:

- To ensure development is constructed to mitigate the risk of flooding and stormwater and that development on flood affected land is constructed to withstand the impact of flooding.
- To ensure development does not increase the flood risk to existing or future development.
- To ensure development of flood affected land is carried out in accordance with the relevant requirements of the Floodplain Development Manual, North Bellbird Rezoning *Floodplain Risk Management and Stormwater Management Strategy* and other relevant legislation, guidelines and controls.
- Development should be carried out so as to make provision for the drainage corridors identified in the above study and minimise damage resulting from flood events.

Requirements:

- Development is to address the relevant requirements of the North Bellbird Rezoning *Floodplain Risk Management and Stormwater Management Strategy* (**Appendices 4 and 5**).

  Note: Not all recommendations of the Strategy will be relevant to the development of the subject land. Applicants and Council are to use their discretion when considering applications for the proposed future development of the land for urban purposes having regard to the zoning of the land.

- For subdivision of land affected by the Probable Maximum Flood (PMF) or land which relies on access through land affected by the PMF, the subdivision design and planning controls shall be designed to consider:
  1. Provision of a flood warning system for Limestone and Bellbird Creeks;
  2. Provision of adequate overland flow paths to minimise inundation depths during extreme events;
  3. Provision of adequate emergency evacuation routes; and
  4. Provision of adequate flood refuge for all affected dwellings.

  Full details will be required to be submitted with the subdivision application and shall address the requirements of the *Floodplain Development Manual* (April 2005).

  Note: *In accordance with the recommendations of the Floodplain Development Manual* (April 2005*) applications for development for the purpose of dual occupancy and multiple dwellings (villas and townhouses), as well as special uses (hospitals, nursing homes, schools and other community facilities as deemed appropriate by Council) shall not be supported on land affected by the PMF.*

- Council <u>may</u> consider applications for development on land affected by the 1 in 100 ARI flood level where it can be demonstrated that:

  - The minimum floor level of any habitable space in a dwelling house must be at least 500mm clear of the identified 1 in 100 year ARI flood level.
  - Applications for development located at or below the 1 in 100 year ARI flood level are accompanied by a detailed report from an appropriate professional demonstrating the building or structure can withstand the force of flowing flood waters, including debris and buoyancy forces, as appropriate.

  - Filling on lots at or below the 1 in 100 year ARI flood level is to be in accordance with the relevant recommendations of the North Bellbird Rezoning *Floodplain Risk Management and Stormwater Management Strategy* and confined to the perimeter of the residential building on that lot and not have adverse impacts on upstream or downstream flood levels and adjoining existing residential development.
  - Fencing located at or below the 1 in 100 year ARI flood level is to be constructed in a manner that does not unduly impede the movement of floodwaters. Full details of proposed fencing are to be submitted with development applications.

- Any required on-site detention (OSD) storage systems must be constructed to serve all new lots before any new dwelling is constructed. OSD storage systems shall be designed so that existing flow rates are not exceeded. The applicant should consult Council's Works Department in regard to the design of the OSD storage system.
- Development applications should be accompanied by a survey from a Registered Surveyor to determine the contours of the land at an interval of 0.5 metres and a vertical datum of Australian Height Datum.

11.4.6 Bushfire

Objectives

- To ensure that development is designed to reduce the risk of bushfire to people and property.

Requirements:

- Areas identified as having a bushfire threat are to be managed to minimise potential risk to people and property.
- All development is to be designed in accordance with the NSW Rural Fire Service (RFS) – Planning for Bushfire Protection guidelines applicable at the time.
- Fire protection measures must be capable of being maintained by owners and users.
- Asset protection zones must be contained wholly within the subject development site.

11.4.7 Section 94 Contributions

Note: Where the proposed development relies on the provision of internal site works, including drainage and flood free access and provision of or upgrades to existing essential services, the developer will be responsible for providing this infrastructure. This also applies where it is Council's opinion that the proposed development results in the need for upgrading or provision of external infrastructure so as to cater for the proposed development and its potential impacts on the natural and built environment.

Objectives

- To ensure that proposed development provides for the appropriate provision and upgrading of infrastructure and services including road infrastructure, off street parking facilities, open space and public recreation and community facilities.
- To ensure that Section 94 Contributions are collected commensurate with the requirements of Council's adopted Section 94 Contributions Plan.

Requirements

- Contributions are payable in accordance with Council's adopted Section 94 Contributions Plan prior to the release of the Subdivision Certificate.

11.5 THE NEED TO REVEGETATE COMPONENTS OF THE NORTH BELLBIRD PRECINCT

Other than the vegetation located within the Brokenback Range and within State Forests, it is estimated that the amount of remnant vegetation in the locality since settlement by Europeans has been reduced to around 10% of its original coverage (Andrews Neil, 1997). The majority of this remaining vegetation is located within road reserves and in patches along creek lines. There are also isolated patches existing in private properties.

The existing remnant patches of vegetation have significance for ecological and visual reasons. Community surveys noted the importance of these areas in maintaining the rural character of the Vineyards District and nearby rural areas (Andrews Neil, 1997).

11.5.1 Why is There a Need to Plant More Trees/Shrubs in the North Bellbird Precinct?

(a) There is a need to preserve, retain and enhance the rural character of the adjoining Vineyards District and it is important to realise the impact of cumulative tree removal on such character.

In recognition of this need, Council has investigated locations for the creation, re-establishment and reinforcement of native vegetation corridors. Details of specifications including depth, species type, fencing and maintenance requirements and the like are contained at **Appendix 2**.

(b) The creation of native vegetation corridors outlined in (a) will assist in the re-establishment of wildlife habitat in the North Bellbird Precinct. It is not possible for native fauna to exist in isolation in the Precinct in the long term. Animals need to be able to move between areas to search for food, shelter and other requirements. This need to move is particularly critical to those species with large territories. Establishment of these corridors will also promote Council's desire to increase the biodiversity of the Precinct and improve the 'physical health' of the current environment.

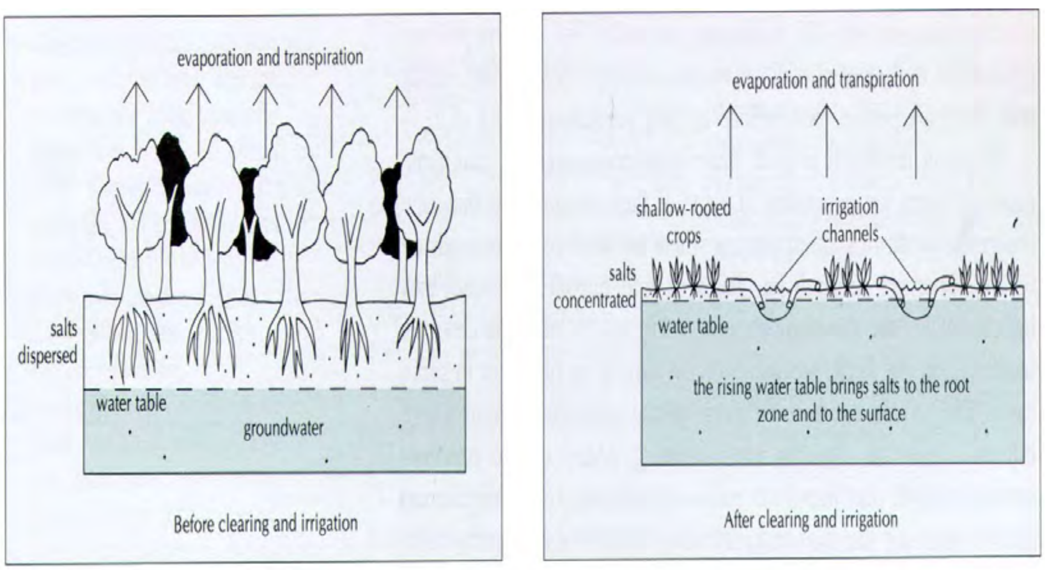
(c) Increased vegetation in the North Western areas of the North Bellbird Precinct will act to capture chemical spray drift in certain locations.

(d) Dryland salinity occurs when deep-rooted vegetation, such as trees, is removed and replaced with shallow rooted plants. These plants use less water and consequently, more water is left to percolate through the soil. The result is an elevated water table which carries dissolved salts. Concentrations of salt will kill vegetation, leaving the ground bare and susceptible to erosion (NSW Agriculture et al. 1989). Increases in tree planting may reduce problems associated with salinity which will directly benefit the viticultural and agricultural operations located within the District and its associated catchment.

(e) Soil erosion occurs through the action of wind and water on soil. Wind erosion is mainly associated with the loss of the finer particles of soil. Water movement over and through the soil can result in sheet, rill, gully and tunnel erosion as well as landslip. Trees, together with understorey and groundcover layers, play a crucial role in intercepting rainfall and reducing the impact of raindrops on the soil surface. Trees help the water soak into the soil and reduce surface runoff. The root system and leaf litter provide structural stability within the soil (NSW Agriculture et al. 1989). The planting of trees will reduce the incidence of land degradation in the North Bellbird Precinct and assist in the rehabilitation of the existing creeklines.

Source: Roach 1998

(f) Trees planted as windbreaks have significant benefits for development and adjoining rural land uses. The area protected by a windbreak is related to the height of the trees. An effective windbreak can reduce windspeed for a distance of up to 30 times the tree height on the downwind side and 5 times the height on the upwind side. The greatest reduction of windspeed is in that part of a property from 5 to 15 times the tree height away from the windbreak (NSW Agriculture et al. 1989)



(Source: Australian Academy of Science, 1994, p. 248)

11.5.2 Native Vegetation Corridors and Mass Plantings

Council is seeking to promote the establishment and enhancement of native vegetation corridors in the North Bellbird Precinct generally in accordance with locations as indicated by **Appendix 1** and details specified in **Appendix 2**. Other mass plantings are also being encouraged in strategic locations.

Note: Often revegetation will occur on land owned and/or operated by Council through dedication of land for Native Vegetation Corridors. The required revegetation is to be undertaken and maintained by the developer as provided for by this DCP and the terms of any relevant development consent.

Objectives

- To ensure that long term character and amenity of riparian corridors is able to be maintained in conjunction with the development of the precinct for urban purposes;
- To enhance native fauna habitat and improve the biodiversity of the area; and
- To promote a more sustainable environment.

Source: Roach 1998

Requirements

- Where an application proposes to develop land affected by a riparian corridor, details of the proposed planting must be clearly specified in the application (both within plans and in the text accompanying the application), including proposed ground preparation, species planting and maintenance and fencing details. Consents issued on this basis will include specific conditions relating to the continued maintenance of such corridors, remaining the responsibility of the land owner, eg. through instruments attached to the title of the property. A refundable bond will be required to the amount of 20% of the total cost of vegetation works (site preparation, plant costs, fencing, etc.). The total amount of the bond will be recoverable at a rate of 20% per year over 5 years where maintenance and survival rates are satisfactory to the Council.
- The locations of native vegetation corridors and other mass plantings are to be modified around existing service lines including electricity, reticulated water, telephone and gas. Whilst the location of these services is generally available from Council's Geographic Information System at a strategic scale, applicants should consult with the relevant servicing authorities to ensure that appropriate locations have been selected.

The clearing of native vegetation is prohibited in areas designated as being native vegetation corridors outlined on the map in **Appendix 1**.

11.6 SPECIFIC REQUIREMENTS FOR LAND ADJOINING LAND ZONED 1(a) RURAL OR 1(v) VINEYARDS

11.6.1 Consideration of Surrounding Land Uses

Objectives

- To reduce the potential for land use conflict between properties by ensuring that subdivisions are designed to have regard to proximity to adjoining commercial vineyards or other agricultural uses so that future dwelling-houses or public places are not located so as to create a situation of potential spray drift impact and noise.

Requirements

- In preparing an application for development, consider the existence and location of surrounding land uses, including viticultural and agricultural activities, and design and site the development in a position which will not result in the potential for land use conflict between neighbouring land uses.

11.6.2 Development Setbacks

<u>Notes:</u>

1. *These particular setback requirements apply to land adjoining land zoned 1(a) rural or 1(v) Vineyards.*
2. *No clearing of land is permitted in areas designated as native vegetation corridors as illustrated in Appendix 1.*

Objectives

- To promote a visually appealing landscape consistent with the rural and viticultural character of the adjoining Vineyards District and rural zoned land, recognising the particular qualities of a site and its surrounds.
- To minimise the impact on the viticultural or agricultural potential of adjoining land.

Requirements

- Council requires a minimum setback of 50 metres to land zoned for rural purposes.
- Council requires a minimum setback of 50 metres for all new dwellings or public place developments to land zoned for rural purposes. However, for applications for extensions or alterations to existing development (not a change of land use) or for applications that do not include a habitable component or constitute a public place development then Council may vary this figure if it can be demonstrated that there are more appropriate locations within the 50 metre side boundary setback.
- Applications for the siting of development within 50 metres of the boundary must be clearly justified.

<u>Note:</u> *The need to provide a chemical spray drift/noise separation distance between a particular (specified) development and existing commercial vineyards on neighbouring land may mean that the required minimum side setback will be in excess of 50 metres.*

11.6.3 Fencing

Objectives

- To inform landowners of the potential impacts of the use of barbed wire fencing on native animals whilst reinforcing the need to contain stock.
- To allow fencing which is consistent with rural and viticultural character.

Council wishes to inform landowners/occupiers of the potential impacts of using barbed wire in their fencing. Advice has been received from the Native Animal Trust Fund (pers. comm. 1998) illustrating that a significant number of animals, particularly bats and squirrel gliders, are being killed or seriously injured as a result of flying into and/or being entrapped in such wire. The squirrel glider *(Petaurus norfolcensis)* is a threatened species under the Threatened Species Conservation Act 1995 and the Commonwealth Endangered Species Protection Act 1992. Wherever possible in the interests of trying to maintain and improve biodiversity and minimise the suffering of our native wildlife it would be appreciated if landowners/occupiers would give strong consideration to the use of plain wire fencing.

<u>Note:</u> *Those landowners/occupiers wishing to promote native animal habitat in the Vineyards District are invited to contact Council's Land Use Planning Section where further advice on suitable tree/shrub planting (eg. for food and shelter) and details of the usefulness of nesting boxes can be provided. Some information on nesting boxes and tree and shrub species selection is contained in* ***Appendix 2.***

Requirements

- Details of the type of fencing to be used, if any, is to be provided with applications for development. Such fencing must be in keeping with the rural and viticultural character of the Vineyards District.

11.6.4 Ground Spraying and Aerial Spraying Considerations

It is important to recognise the potential impacts associated with chemical spray drift, whether those chemicals are applied from the air or from the ground.

Objectives

- To ensure that specified new development is appropriately sited having regard to the location of <u>neighbouring</u> commercial vineyards, reducing the potential for impacts associated with chemical spray drift from both the ground and aerial application of chemicals.
- To incorporate the use of vegetation chemical spray drift buffers as a means to capture chemical spray drift and reduce the required separation distance between commercial vineyards and specified developments.

<u>Note:</u> *By ensuring that these objectives are achieved, Council is seeking to reduce the incidence of land use conflict between properties with commercial vineyards and those with developments having 'human habitation' components. It is important to ensure that vineyard operators are not forced to modify their practices due to complaints received from surrounding occupants. Similarly, it is equally important to ensure that surrounding occupants and their livelihood are not at risk from either the perceived or real impacts associated with chemical spray drift.*

- To <u>encourage</u> both the physical separation of commercial vineyards and specified developments within a property and the establishment of vegetation chemical spray drift buffers between commercial vineyards and specified developments to reduce the potential for chemical spray drift and noise impacts <u>within that property</u>.

Requirements

All dwelling-houses referred to in this section include a reference to manager's residences as they apply to managers of both viticultural and tourist-related properties.

1. NEW PUBLIC PLACE DEVELOPMENTS AND DWELLING-HOUSES: SITING REQUIREMENTS RELATED TO THE POTENTIAL FOR CHEMICAL SPRAY DRIFT

(i) Vacant Adjoining/Adjacent Land With No Approvals for Commercial Vineyards

New public place developments and dwelling-houses are to be set back a minimum of 50 metres from a *property boundary* where no existing or approved commercial vineyards are on adjoining or adjacent land.

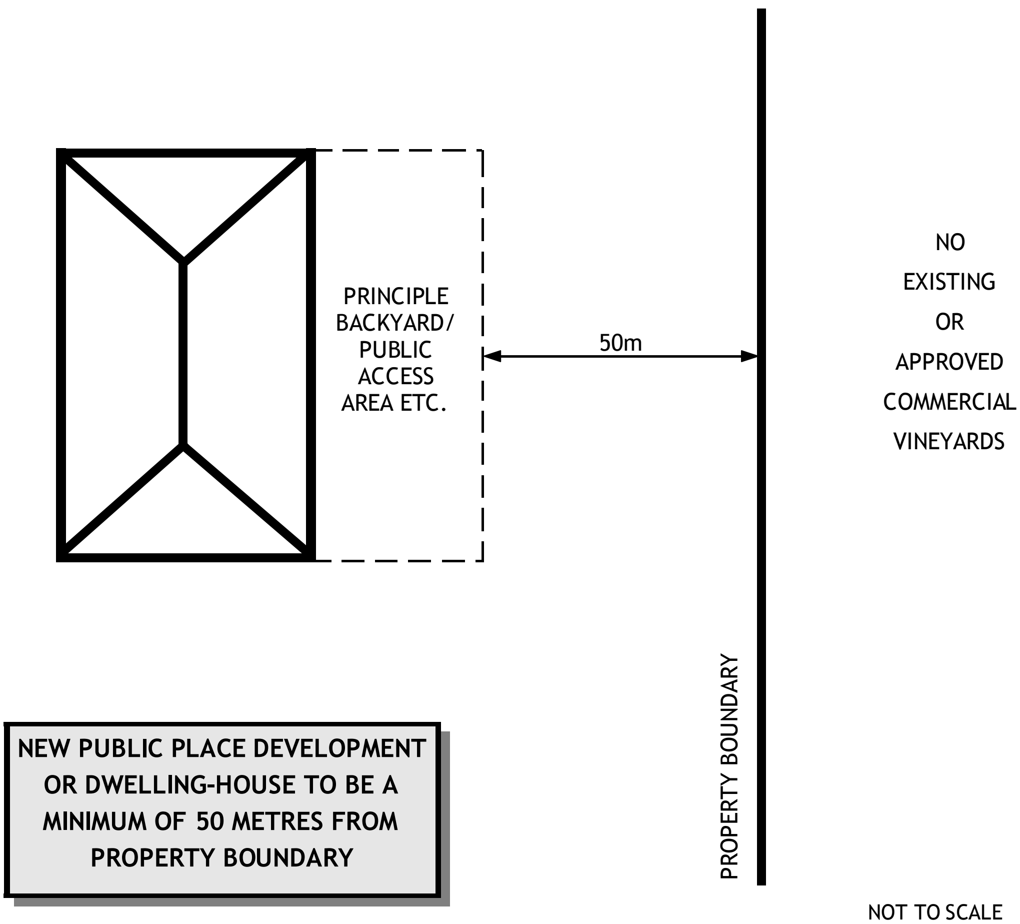


FIGURE 4

(ii) With Adjoining/Adjacent Existing or Approved Commercial Vineyards

Two methods (a) and (b) are available to minimise the incidence of chemical spray drift impact on new public place developments and dwelling-houses. The applicant is to select the most appropriate method.

(a) New public place developments and dwelling-houses are to have a minimum separation distance of 100 metres from an existing or approved commercial vineyard on adjoining or adjacent land.

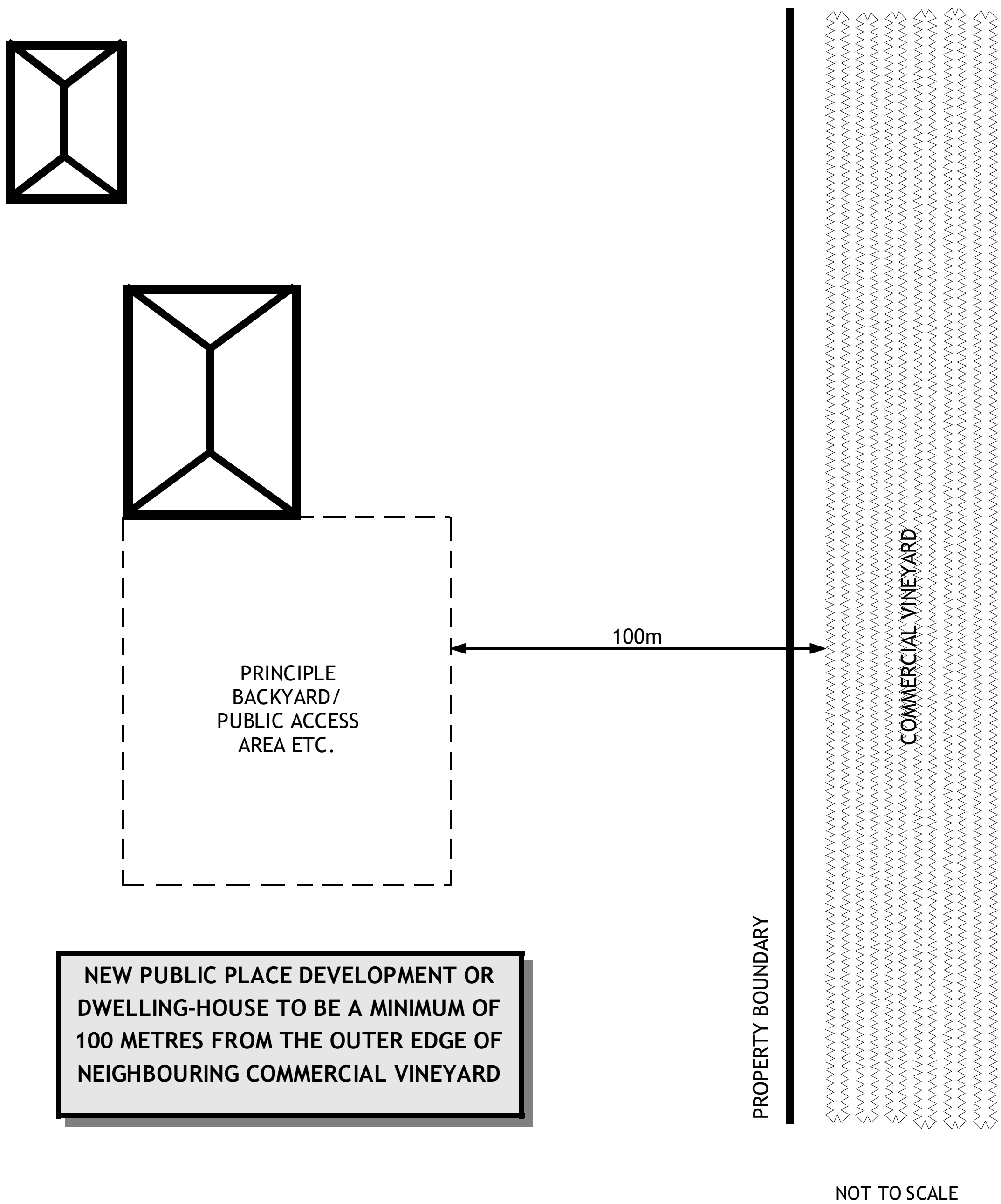


FIGURE 5

(b) New public place developments and dwelling-houses are to have a minimum separation distance of 80 metres (which incorporates a vegetation chemical spray drift buffer of minimum 30 metre depth - length and location to be determined on merit) from an existing or approved commercial vineyard on adjoining or adjacent land.

There are specific requirements for the establishment of vegetation chemical spray drift buffers which are contained at Appendix 2.

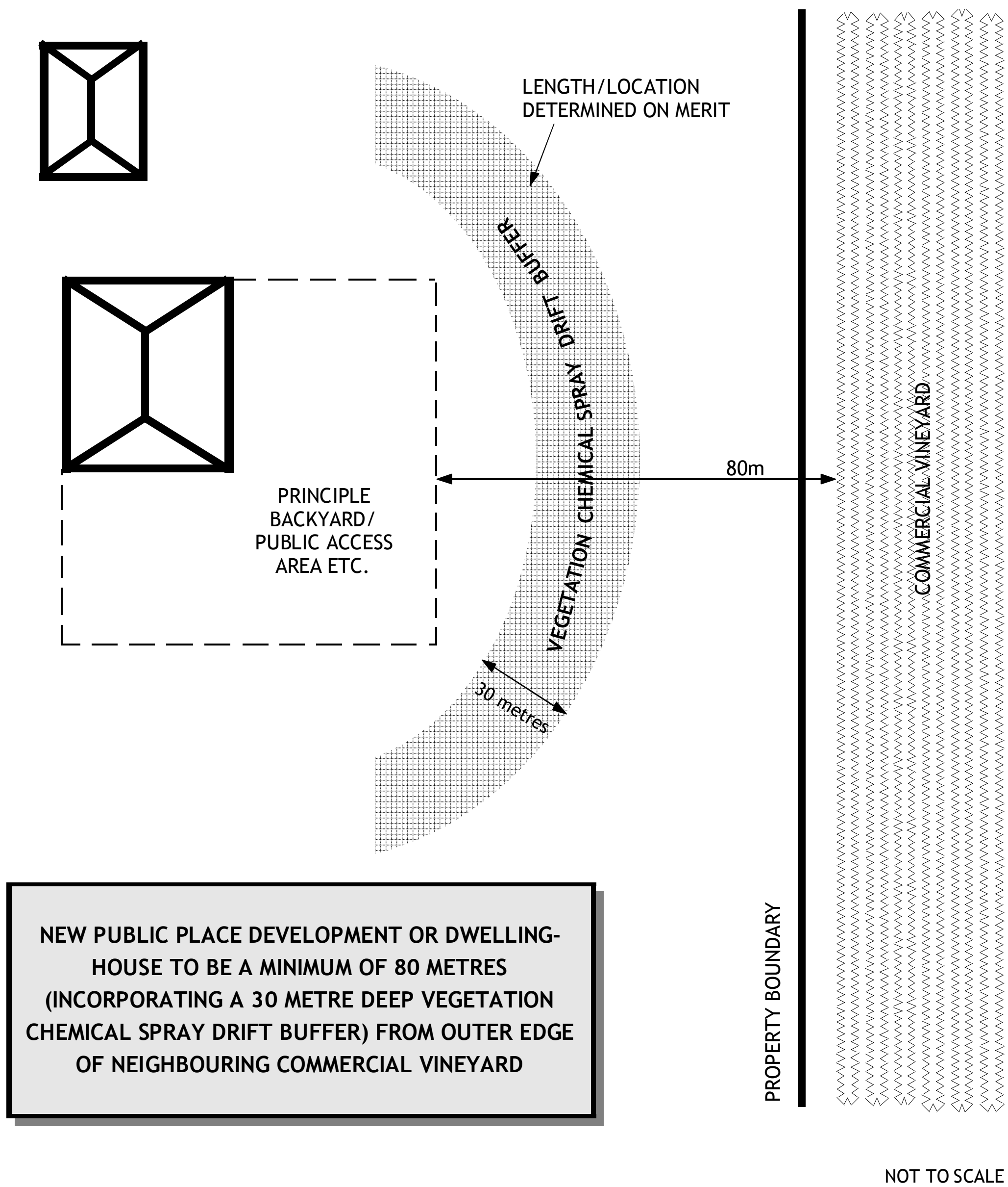


FIGURE 6

REFERENCES

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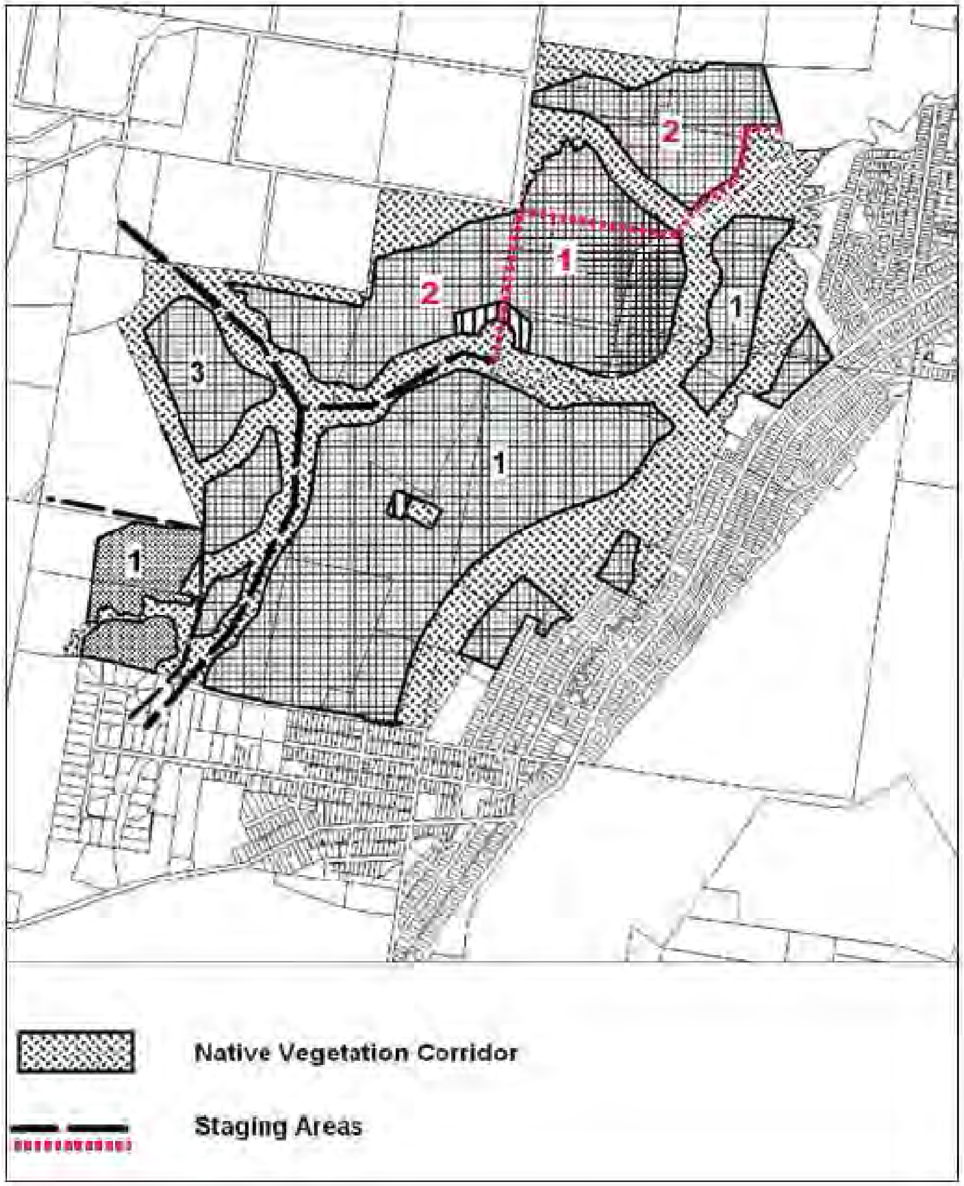
APPENDIX 1

NORTH BELLBIRD PRECINCT

STAGING PLAN
AND
NATIVE VEGETATION CORRIDORS


2
1
2
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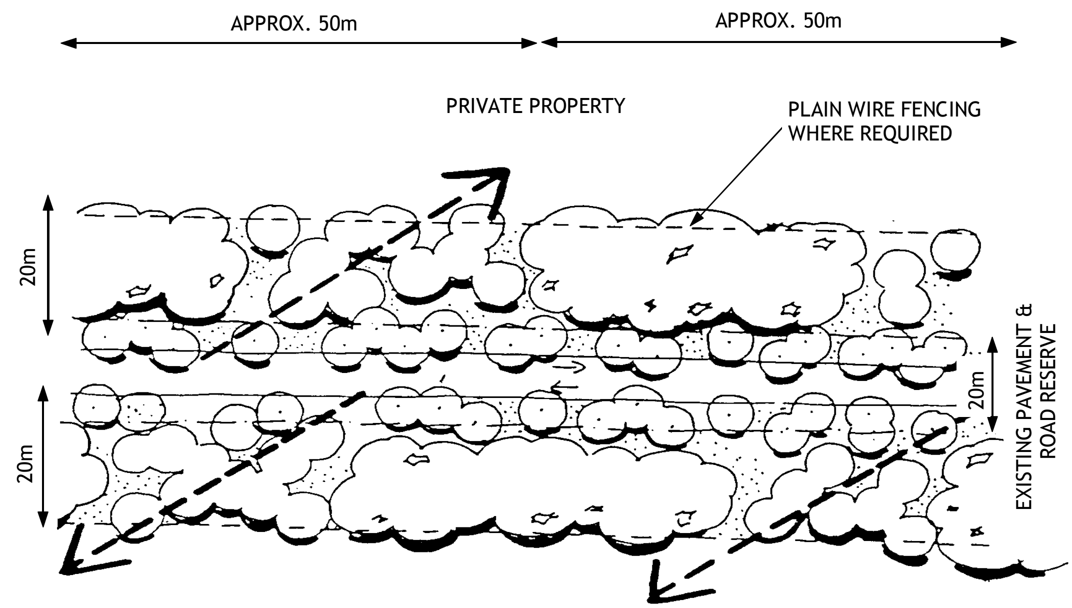
3
1
1
Native Vegetation Corridor
Staging Areas

APPENDIX 2

NORTH BELLBIRD PRECINCT

NATIVE VEGETATION CORRIDORS AND MASS PLANTING GUIDELINES

TYPICAL PLANTING LAYOUT – ROADSIDE CORRIDORS



ROAD RESERVE

PLAIN WIRE FENCING WHERE REQUIRED

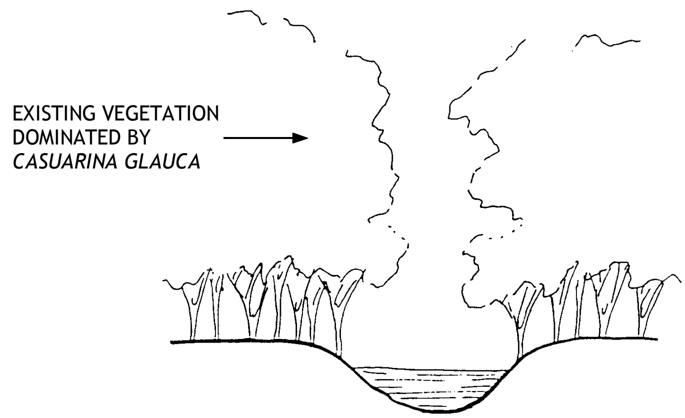
EXISTING TREES IN ROAD RESERVE

TREE/SHRUB PLANTING IN PROPOSED 20m NATIVE VEGETATION CORRIDOR

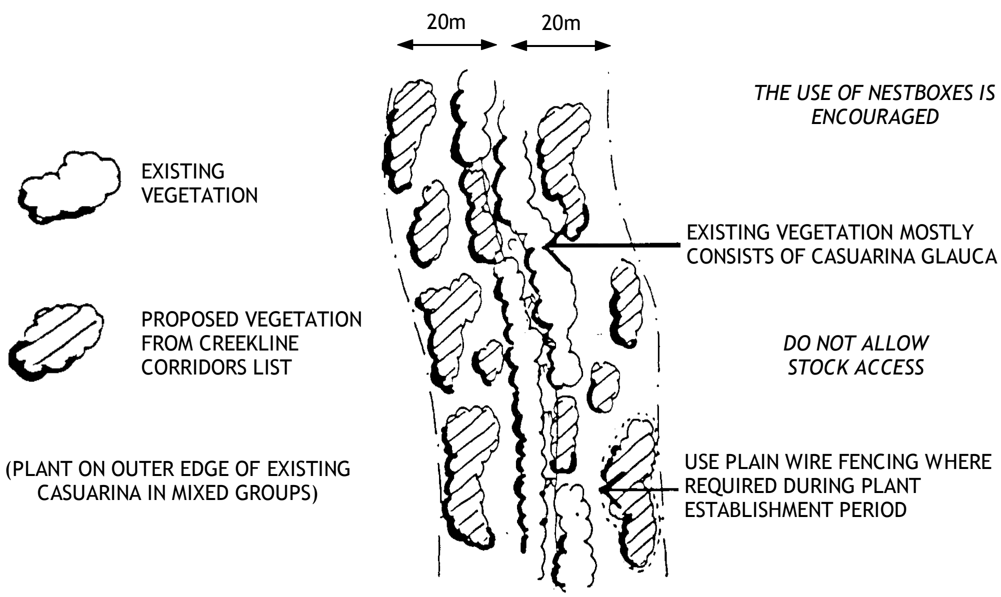
GRASSY UNDERSTOREY

THE PROPOSED PLANTING SCHEME CREATES HABITAT CORRIDORS & MAINTAINS FILTERED VIEWS ACROSS THE DISTRICT

THE USE OF NESTBOXES IS ENCOURAGED



TYPICAL DETAIL OF EXISTING CREEKLINES



TYPICAL PLANTING LAYOUT – CREEKLINE CORRIDORS

SUGGESTED PLANTING LISTS - ROADSIDE CORRIDORS

Tree and shrub species have been selected through consultation with various organisations (including Greening Australia, the Native Animal Trust Fund and the Society for Growing Native Plants) and through local knowledge of the Vineyards District. Several species have been selected due to their importance as food and habitat sources for various known local populations of insectivorous bats, possums, gliders and koalas, of which some species, such as the Squirrel Glider (Petaurus norfolcensis) and the Koala (Phascolarctos cinereus), are listed as 'vulnerable' in the NSW Threatened Species Conservation Act 1995 and the Commonwealth Endangered Species Protection Act 1992.

In general, tree and shrub species have been selected to enhance biodiversity and provide wildlife habitat. However, by following the planting layouts contained in this Appendix, views will be preserved and the rural character of the adjoining Vineyards District will be enhanced.

Scientific Name	Common Name	Flowering Time	Height (m)
Trees			
Allocasuarina torulosa	Forest Oak		20
Brachychiton populneum	Kurrajong	Summer	10-20
Casuarina glauca	Swamp Oak		15
Corymbia maculata	Spotted Gum	Late Summer - Autumn	36
Eucalyptus acmenoides	White Mahogany	Oct - Feb	36
Eucalyptus amplifolia	Cabbage Gum	Summer	30
*Eucalyptus glaucina**	Slatey Red Gum		30
Eucalyptus moluccana	Grey Box	Late Summer - Autumn	30
Eucalyptus paniculata	Grey Ironbark	Winter - Spring	30
Eucalyptus piperita	Sydney Peppermint	Early Summer	15
Eucalyptus punctata	Grey Gum	Summer - Autumn	30
Eucalyptus tereticornis	Forest Red Gum	June - Nov	40
Shrubs			
Acacia parramattensis	Parramatta Green Wattle	Late Nov - Early Feb	8
Acacia parvipinnula	Silver Stemmed Wattle	Sept - Early Dec	10
Acacia falciformis	Broadleaved Hickory	Oct - Jan	3-12
Acacia filicifolia	Fern Leaf Wattle		13
Acacia fimbriata	Fringed Wattle	July - Sept	5-7
Acacia longifolia	Sydney Golden Wattle	July - Nov	5
Bursaria spinosa	Blackthorn	Jan - April	10
Dodonaea triquetra	Hop Bush	Spring - Summer	2
Leptospermum parvifolium		Sept - Nov	15
Leptospermum trinervium	Paperbark Tea Tree	Spring	3
Olearia eliptica	Sticky Daisy Bush	Spring - Summer	0.50-1
Oxylobium ilicifolium	Native Holly	Spring	2
Persoonia linearis	Geebung	Dec - July	3

SUGGESTED PLANTING LISTS - CREEKLINE CORRIDORS

Trees

Scientific Name	Common Name	Flowering Time	Height (m)
Casuarina glauca	Swamp Oak		20

To increase diversity plant a mix of the following on the outer edge of existing *Casuarina* communities.

Scientific Name	Common Name	Flowering Time	Height (m)
Angophora floribunda	Rough Barked Apple	Spring - Summer	20-35
Casuarina cunninghamina	River she-oak		36
Corymbia maculata	Spotted Gum	Late Summer - Autumn	25
Eucalyptus albens	White Box		30
Eucalyptus amplifolia	Cabbage Gum	Summer	30
Eucalyptus crebra	Narrow-Leaved Ironbark	May - Jan	30
Eucalyptus fibrosa	Broadleaved Ironbark	Nov - Jan	30
Eucalyptus punctata	Grey Gum	Summer - Autumn	30
Eucalyptus resinifera	Red Mahogany	Nov - Jan	25-30
Eucalyptus saligna	Sydney Blue Gum	Jan - Mar	30-50
Eucalyptus tereticornis	Forest Red Gum	June - Nov	30-40
Tristania laurina	Water Gum	Dec - Jan	4-10

Shrubs

Scientific Name	Common Name	Flowering Time	Height (m)
Acacia parvipinnula	Silver Stemmed Wattle	Sept - Dec	4-10
Acacia pycnantha	Golden Wattle	Spring	8
Breynia oblongifolia	Breynia		2-3
Bursaria spinosa	Blackthorn	Jan - April	2-3
Callistemon citrinus	Red Bottlebrush	Spring	2
Callistemon linarifolius		Spring	2-5
Callistemon salignus	Weeping Bottlebrush		3-4
Dianella spp.	Flax Lily		1
Dodonaea triquetra	Hop Bush	Spring - Summer	2
Gahnia aspera	Sedge		0.40-0.60
Lomandra spp.	Rush		0.75-1.3
Melaleuca nodosa	Ball Honeymyrtle	October	6
Olearia eliptica	Sticky Daisy Bush	Spring - Summer	0.50-1

ELSEWHERE

Select from roadside and creekline corridor species lists as appropriate. However, creekline corridor species generally require more soil moisture than do the suggested roadside corridor species.

N.B. The following are particularly useful food and habitat species for possums, gliders, koala and insectivorous bat populations in the Vineyards District.

- *Acacia pycnantha* and *A. parvipinnula* are useful feed trees for the Squirrel Glider (*Petaurus norfolcensis*).
- *Acacia spp.* (in particular *A.fimbriata*) are generally useful as insect attractants for possums, gliders and insectivorous bats. They also provide a source of sap and seeds for particular glider and possum species.
- Eucalypts are useful in providing habitat and food sources for insectivorous bats, possums and gliders. They are also effective in attracting insects which are an important component of the diet of numerous insectivorous bat, glider and possum species.
- *Eucalyptus tereticornis, E. punctata and E. albens* are important feed trees for local Koala populations.
- *Eucalyptus paniculata* is a useful habitat tree as it readily forms hollows when mature.
- *Eucalyptus glaucina** is classified as 'vulnerable' under the NSW Threatened Species Conservation Act, 1995.

SPECIES SELECTION GUIDE

Creekline Corridors

A mix of 60% of total species should be selected from the *creekline corridor shrub list* with a further 40% of total species being selected from the *creekline corridor tree list*.

For example, for every 100 trees, 60 should comprise a mix of species listed in the creekline corridor shrub list and 40 should comprise a mix from the creekline corridor tree list.

Roadside Corridors

A mix of 50% of total species should be selected from the *roadside corridor shrub list* with a further 50% of total species being selected from the *roadside corridor tree list*.

For example for every 100 trees, 50 should comprise a mix of species listed in the roadside corridor shrub list and 50 should comprise a mix from the roadside corridor tree list.

Species selection should aim to provide year round flowering.

PLANTING PREPARATION

The following is a general prescription for establishing native roadside and creekline vegetation corridors as well as for plantings in general.
Details following in this Appendix have been provided by Greening Australia (1998).

Calendar for planting

12 months before planting

- Design a plan to establish the location of the planting, species selection from the lists within this Appendix, dimensions of site for planting and what alternatives are available.

9 months before planting

- Order your seedlings from your local nursery. If you have collected your own seed start propagating now.
- Deep rip the site in rows or a grid pattern. This is best on most soils, however black soils or cracking earths are best cultivated. Mounding of waterlogged or very damp sites on heavy soils will assist with growth. Soils which are considered moderate to highly erodable may not be suitable for deep ripping. (Advice from the Department of Land & Water Conservation should be sought).
- To deep rip or cultivate within the riparian zone (approximately 40 metres either side of a creek) you may require permission from the Department of Land & Water Conservation.
- Continue to allow grazing to reduce pasture.

6 months before planting

- Apply a knockdown herbicide along rip lines or cultivate several times to reduce weeds.
- Fallow to build up moisture. Continue to allow grazing to reduce pasture.
- Fence the site, leaving space between outside rows and the fence of about 3 metres to restrict stock from grazing your growing plants from over or through the fence. Also leave space for machinery to get in and out of the site.

2 to 3 weeks before planting

- Apply a Glyphosate based herbicide or grade over the riplines to remove weeds and weed seeds. Grading should be a scalping process at least one metre wide. Residual herbicides give long term protection from weeds, however care must be taken. Herbicides should only be used in accordance with legislation and safety handling data. Consult with your local Weed Control Officer at the Council.

When to establish native plants

Generally, plant establishment is carried out mid March to late April throughout the Hunter. This is usually the period of greatest rainfall and soil temperatures provide conditions for optimum germination and growth. Planting times will vary dependent on local climatic conditions. ***Only plant seedlings when the soil is moist.***

Location

- Plant species in mixed groups of 3 to 5.
- Randomly locate groups with a maximum of 15 metres between each group.
- Infill planting around existing vegetation. Do not plant within the dripline of existing trees.
- All areas subject to detailed site analysis prior to commencement.

Planting

- Only plant as many seedlings in a day that can be watered in that same day. When planting, dig a hole about twice the size of the seedling pot, fill some loose soil back in, place the seedling in the hole (you do not have to 'tease' the roots of native plants) and gently fill the remaining soil back around the plant.
- Tubestock should be planted between 1.5 and 8 metres apart depending on the species selected.
- With a foot on either side of the seedling, press down firmly. This will help hold the seedling in place and remove air pockets.
- Watering after planting should be the only time the plants are hand watered. A 10 litre bucket of water for each seedling should be sufficient. Planting after or during rain is often easier.
- Mulch around stem to 500mm diameter - avoid direct contact of mulch with stem to avoid trunk rot.
- Guard seedlings to protect against rabbits, hares, wallabies, frosts and to help with moisture retention. Tree guards should be installed at the time of planting. Use milk cartons with two stakes, or mesh or plastic with three stakes. Plastic tree guards can usually be removed after twelve months (and can be reused!).
- Seedling establishment can be carried out with tree planting machinery, dependent on the size of the site and the suitability of the machinery to the site.

Follow - up

- Follow up watering should not be necessary with good ground preparation and soil moisture at the time of planting.
- Weed control will usually be needed as a follow up to planting. Good weed control prior to planting can avoid this. Any weed control chemical application should be done using equipment which ensures no contact of the chemical with seedlings. Hand weeding is a safer option.

Direct Seeding

- Direct seeding is a cost-effective and efficient method of establishing large numbers of native plants. Direct seeding is simply the direct sowing of native plant seed to the soil where you wish to establish trees and shrubs. Advantages of direct seeding include lower costs as seed is usually cheaper to purchase or collect than tubestock; a more natural look or mix of trees and shrubs and that mature plants are usually more stable as their root systems have not been restricted or disturbed.

- Successful direct seeding is usually achieved by good site preparation, effective seed preparation, sowing at the correct time (when soil is moist and the soil temperature is warm).
- Site preparation is a critical component of tree and shrub establishment by direct seeding. Any direct seeding site should have minimal weed infestation and competition. Methods of site preparation include grading or scraping the soil surface to remove weeds, chemical application using a residual pre-emergent herbicide and a knockdown herbicide prior to direct seeding and cultivation of the site prior to direct seeding.
- Seed may need pre-treatment depending on the species being used. To combat the ants taking seed for their "lunch ", seed is usually treated with an low toxicity insecticide.
- On slopes steeper than 1:3, a bituminous binder should be added to the seed slurry.
- There are many methods of direct seeding. Row seeding, spot seeding and belt seeding are the most common.

- **Row seeding** is usually carried out using a single row seeding machine. This method is efficient for lengthy rows on windbreaks or shelterbelts and ensures the seeding application rate is sufficient. Row seeding can also be a done in figure eights or cross over lines to give a more natural and random effect. Weed control and maintenance is also easy along the sides of the rows.

- **Spot seeding** is usually carried out by hand and can be very effective at appropriate sites. Spot seeding may be used for sites where machinery will not be effective such as rocky sites or inaccessible sites. Other times to use spot seeding is when machinery may cause serious erosion problems, such as near creeks or if the site is too small to warrant using machinery. A hoe is often the best tool for carrying out spot seeding.

- **Belt seeding** is simply the term used for wide belts or areas of direct seeding. Often belt seeding is carried out by converted agricultural machinery or using a fertiliser spreader.

FUNDING SOURCES - VOLUNTARY PLANTING

Financial assistance related to the planting of native vegetation is available from a number of sources including the Department of Land and Water Conservation, the Hunter Catchment Management Trust and those avenues outlined in the ‘Funding Calendar’, produced annually by WESTIR Limited (Western Sydney Regional Information and Research Service). A copy of the Funding Calendar is available for viewing at Council’s Strategic Planning Section. Copies can be purchased directly from WESTIR on (02) 9622 3011.

APPENDIX 3

NORTH BELLBIRD PRECINCT SPECIFICATIONS FOR VEGETATION CHEMICAL SPRAY DRIFT BUFFERS

VEGETATION CHEMICAL SPRAY DRIFT BUFFERS

- Research into the behaviour of chemical spray drift has shown that vegetation chemical spray drift buffers can prove effective barriers to spray drift where they meet the following criteria:
  1. Are of minimum width of 30 metres;
  2. Contain random plantings of a variety of tree and shrub species of differing growth habits, at spacings of 4 to 5 metres;
  3. Include species which have long, thin and rough foliage which facilitates the more efficient capture of spray droplets (see accompanying species list); and
  4. Provide a permeable barrier which allows air to pass through the buffer (at least 50% of the buffer should be open space).

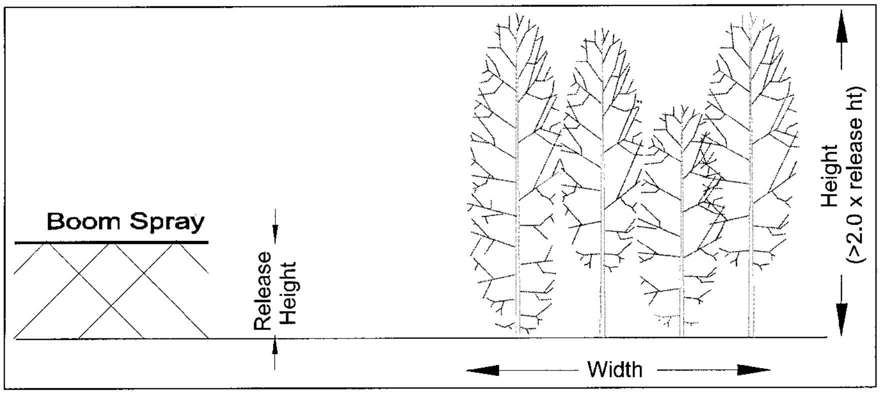
  (Lismore City Council, 1994, p. 3)
- The vegetation chemical spray drift buffer shall have a minimum width of 30 metres and shall be designed in accordance with the following diagrammatic details incorporating species from the accompanying species list.
- Locations are to be determined individually through merit-based assessment.
- In the case of development consents for urban purposes, Council will require the establishment of the required vegetation chemical spray drift buffer and any associated fencing to be constructed prior to the subdivision certificate.
- Consents issued on this basis will include specific conditions relating to the continued maintenance of such buffers, remaining the responsibility of the developer, eg. through instruments attached to the title of the property. A refundable bond will be required to the amount of 20% of the total cost of vegetation works (site preparation, plant costs, fencing, etc.). The total amount of the bond will be recoverable at a rate of 20% per year over 5 years where maintenance and survival rates are satisfactory to the Council.
- Applications for development, where vegetation chemical spray drift buffers are proposed, shall include a detailed landscaping plan indicating the extent of the buffer area, the location and spacing of trees and shrubs and a list of tree and shrub species. The application shall also contain details showing means by which the buffer is to be maintained.

The Draft National Guidelines for Spray Drift Reduction of Agricultural Chemicals prepared by the Centre for Pesticide Application and Safety indicate that:

1. Plant surfaces which present a small frontal area to the moving chemical droplets are the most successful at catching these droplets. Trees in the casuarina species are particularly useful. Large leaves that are covered in small hairs can also be efficient at removing droplets. Aim to provide foliage which extends from the base to the crown. Mixed plantings of trees and shrubs may be required to ensure that there are no gaps in the lower canopy.

2. A porous buffer (which has sufficient air movement through the vegetation) will remove a greater number of spray droplets than a solid barrier. A porosity of about 50% should be sought (approximately 50% of the buffer should be air space).

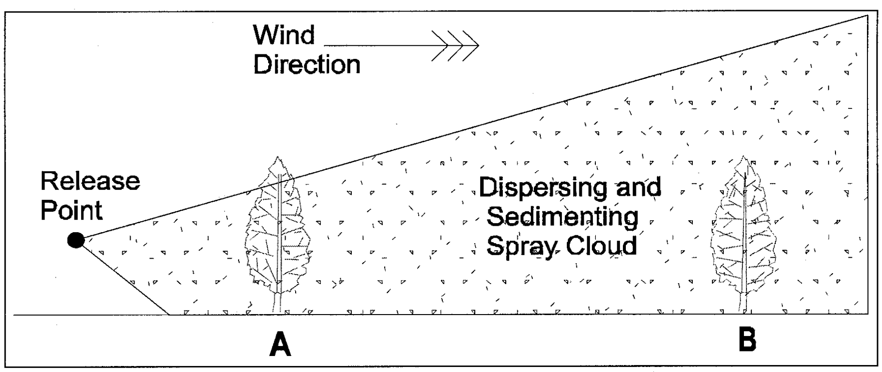
3. As a general guide, the minimum height of the buffer should be double the release height of the chemical. For example, if chemicals are released at a height of 2 metres, then the buffer height should be at least 4 metres in height.



Optimum vegetative buffer dimensions

4. The wider the buffer the greater the effectiveness of the buffer in reducing spray drift.

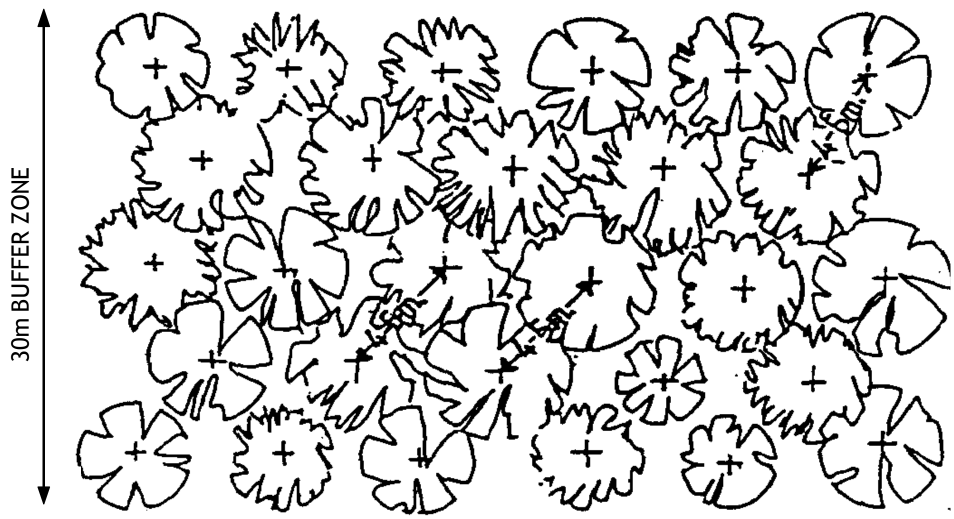
5. The closer the buffer to the release point, the greater the proportion of spray which will be intercepted. The vegetation buffer should, therefore, be as close as practical to the spray zone. (This can obviously create difficulties in instances where the onus is on the built development to provide the vegetation buffer. Each of those circumstances should continue to be considered on merit as currently required by this chapter).



Effect of distance from release point

Source: Centre for Pesticide Application & Safety, 2000, Draft National Guidelines for Spray Drift Reduction of Agricultural Chemicals, University of Queensland.

VEGETATION CHEMICAL SPRAY DRIFT BUFFER SPECIFICATIONS



PLAN VIEW

SECTION VIEW

Source: Centre for Coastal Management, 1995, P. 74.

RECOMMENDED VEGETATION SPECIES FOR VEGETATION CHEMICAL SPRAY DRIFT BUFFERS

Tree/Shrub	Height	Growth Rate	Soil
Broadleaved Hickory *Acacia falciformis*	5 to 12 metres	Fast	Sandstone and rocky soils
Fern Leaf Wattle *Acacia filicifolia*	6 to 10 metres	Fast	Grows best in clay loam, silt
Fringed Wattle *Acacia fimbriata*	10 to 15 metres	Fast	Grows best on deep moist acid soil
Sydney Golden Wattle *Acacia longifolia*	5 to 6 metres	Fast	Prefers moist, acid soils, although grows in other conditions
Blackwood *Acacia melanoxylon*	10 to 20 metres	Fast	Grows best on deep moist acid soil
Parramatta Green Wattle *Acacia parramattensis*	To 8 metres	Fast	Dry, shallow sandy or clay soils
Silver Stemmed Wattle *Acacia parvipinnula*	To 10 metres	Fast	Sandy soils, especially along creek lines
Black Oak *Allocasuarina littoralis*	8 to 10 metres	Moderate	Grows well on both poor and well drained acid soils
Forest Oak *Allocasuarina torulosa*	15 to 20 metres	Moderate	Will grow on light soils but more suited to the better types
Honeysuckle *Banksia integrifolia*	12 to 18 metres	Fast	Poor, low phosphorous soil (don’t fertilise), well or poorly drained soil
White Bottlebrush *Callistemon salignus*	5 to 7 metres	Fast	Light to heavy soil. Frost tolerant.
White Cyprus *Callitris columellaris*	10 to 20 metres	Moderate	Frost resistant, prefers sandy loamy soil.
River Oak *Casuarina cunninghamiana*	10 to 20 metres	Fast	Good, well drained loam, needs plenty of moisture, responds to irrigation.
Swamp Oak *Casuarina glauca*	10 to 12 metres	Fast	Moisty, will grow on marshy or saline soil or poorly drained pug.
Tuckeroo *Cupaniopsis anarcardioides*	5 to 10 metres	Fast (if fertilised)	Good to medium heavy clay and loamy soils
Hop Bush *Dodonaea triquetra*	To 2 metres	Moderate - fast	Grows best in heavy soil
Red Bloodwood *Eucalyptus gummifera*	18 to 30 metres	Fast	Hardy, grown on a wide range of soils
Willow Leaf Hakea *Hakea salicifolia*	5 to 7 metres	Fast	Grows well on acid soils with good drainage
Lemon Scented Tea Tree *Leptospermum petersonii*	6 to 10 metres	Fast	Light to heavy soil but not waterlogged, responds to hedging.
Paperbark Tea Tree *Leptospermum petersonii*	10 to 12 metres	Moderate	Grows well in most soils
Broad Leaved Paperbark *Melaleuca quinquenervia*	15 to 20 metres	Fast	Light to medium clay, low frost tolerant, can withstand heavy and long term flooding.
Prickly Leaved Paperbark *Melaleuca styphelioides*	5 to 8 metres	Moderate	Grows well on damp, brackish soils and heavy clays.
Sticky Daisy Bush *Olearia eliptica*	To 1 metre	Moderate	Grows well in sandy/light loam soil

Sources: Centre for Coastal Management, 1995. Cessnock City Council, 1998.

APPENDIX 4

NORTH BELLBIRD PRECINCT

Floodplain Risk Management and Stormwater Management Strategy – Patterson Britton & Partners Pty Ltd, dated August 2007.

Johnson Property Group

North Bellbird Rezoning

Floodplain Risk Management and Stormwater Management Strategy

Issued: August/ 2007

Patterson Britton
& Partners Pty Ltd

consulting engineers

North Bellbird Rezoning

Issue	Description of Amendment	Prepared by (date)	Verified by (date)	Approved by (date)
1	DRAFT	CK / BGP [17.07.07]		
2	Final Report for Authority Review	CK / BGP [30.07.07]	BKP 13/08/07	BKP 13/08/07

Issue No. 2

Note:

This document is preliminary unless it is approved by principal of Patterson Britton & Partners.

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EXECUTIVE SUMMARY

In March 2007, Patterson Britton and Partners were engaged by *Johnson Property Group* (*JPG*) to examine the flooding, stormwater and riparian corridor constraints for a proposed residential development located at North Bellbird. This investigation was requested by JPG in response to comments from *Department of Natural Resources* (*DNR*) in a letter dated 10^{th} of November 2006. This letter is attached in **Appendix K.**

The following table outlines the *DNR* comments and refers the reader to the appropriate section of the report.

DNR Comment / Requirements	Relevant Section of Report
Assessment of Riparian Corridor Requirements - assessment of the riparian corridors under the *Rivers and Foreshores Improvement Act, 1948*	**Section 6** discusses the methodologies used to determine the riparian corridor requirements, as well as recommending creek line rehabilitation works and recommended riparian setbacks
Riparian and Remnant Vegetation Management – assessment of remnant vegetation extents and proposed rehabilitation areas.	**Section 6** assesses remnant vegetation extents and outlines proposed revegetation areas.
Wetlands – assessment of remnant wetlands within the site.	An assessment of remnant wetlands is discussed in **Section 6**, proposed stormwater controls are discussed in **Sections 5** and **7**
Farm Dams – an assessment of the existing and proposed use of farm dams as well as an assessment of the harvestable rights allowance required by the *Water Management Act, 2000.*	An assessment of the existing and proposed harvestable rights is discussed in **Section 6**.
Stormwater control and Treatment – Establishment of stormwater control strategies	Recommended stormwater controls are discussed in **Section 3** (runoff quantity) and **section 5** (runoff quality). Resulting DCP recommendations are detailed in **Section 7.**
Floodplain Management – an assessment of the suitability of the land in accordance with NSW Governments *Floodplain development Manual, 2005*.	**Section 3** discusses the local and regional hydrology. **Section 4** discusses the predicted flood behaviour over the site, including hydraulic and hazard categorisation of flood prone land within the site and a preliminary assessment of flood warning , access, evacuation and emergency measures. DCP recommendations for development are detailed in **Section 7**
Groundwater and Salinity	A groundwater and salinity assessment is concurrently being undertaken by Douglas Partners.

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1 INTRODUCTION

1.1 BACKGROUND

The existing township of Bellbird is a residential and rural area with a population of approximately 2,500. It is located within the Cessnock City Council Local Government Area (*Council*) which lies to the west of Newcastle in the Lower Hunter Valley and has a relatively stable population.

In March 2007, Patterson Britton and Partners were engaged by Johnson Property Group (*JPG*) to examine the flooding, stormwater and creek rehabilitation constraints for a proposed residential development located at North Bellbird. The proposed development site is located to the northwest of the existing Bellbird township and is bounded by Tennant Street to the south, Bellbird Creek to the east, Mount View Road to the north and existing vineyards and grazing lands to the west.

Refer to **Figure 1** for site locality plan**.** It is envisaged that this land will be rezoned and developed to ultimately accommodate up to approximately 3,500 lots. It comprises 497 hectares of undulating rural land which has been utilised for a range of agricultural pursuits since European settlement. Archaeological findings also suggest that sections of the site have historically been used by indigenous peoples prior to settlement.

Cessnock City Council is currently assessing the rezoning proposal for the North Bellbird site. The rezoning proposal is progressing within Council and is anticipated to be finalised shortly.

Upon rezoning, JPG intend to lodge a Development Application for the first stage of the development. It is noted that the development of the site for the proposed residential purposes is consistent with both the *Lower Hunter Regional Strategy* [(19)] as prepared by the NSW Department of Planning and Cessnock City Council's own *City Wide Settlement Strategy* [(18)].

1.2 STUDY OBJECTIVES

Patterson Britton and Partners were engaged to assess the stormwater, flooding and creek rehabilitation constraints for the site. Accordingly, the following study objectives have been established:

- Assessment of the existing and developed state hydrology, including an assessment of the likely impacts of development on local and regional hydrology;
- Establishment of an appropriate detention policy to minimise the effects of urban development on local and downstream flooding;
- Assessment of the flood behaviour over the site during a range of flood events, defining flood extents, delineation of Floodways and assessment of provisional flood hazard over the site in accordance with the principles in the *Floodplain Development Manual* [(9)];
- Assessment of the potential flood impacts on adjoining and downstream properties as a result of the proposed development;

- Development of a stormwater management strategy which mitigates the water quality and quantity impacts of the proposed development on receiving waters;
- Assessment of the current state of on-site creek systems and recommend creek rehabilitation works and upstream setback corridors;
- Assess the impacts of existing farm dams and proposed stormwater management measures in terms of Harvestable Rights under the *Water Management Act* [(22)]; and
- Collate the results from the engineering investigation and establish development planning controls and a recommended stormwater and flood management plan for the site.

1.3 SITE DESCRIPTION / PROPOSED DEVELOPMENT

The investigation area comprises of an approximate 497 ha parcel of land located to the northwest of the existing Bellbird township. Currently, the majority of the site consists of cleared land which is used for cattle grazing. There are some pockets of remnant bushland in the south-western and eastern portions of the site.

A recent site survey, including existing land tenure, is presented in **Figure 3.**

A detailed description of the on-site water courses is provided in **Section 2.**

The current proposed development master plan is intend to ultimately develop the site to include:-

- A mix of residential uses;
- Retail and commercial opportunities;
- A local primary school;
- Recreational facilities; and
- Open space and conservation areas.

The proposed development will have a rural village/community atmosphere and will be separate in locality and perception from the neighbouring existing townships of Bellbird, Bellbird Heights and Cessnock. All infrastructure services including roads, drainage, water, sewer, power, telecommunications, cycleways and landscaping will be provided.

Refer to **Figure 2** for the proposed development master plan, as developed by *Andrews Neil*.

1.4 PREVIOUS STUDIES

To date, the following flooding and stormwater investigations of the North Bellbird study area (*and the greater Cessnock Area*) have been undertaken.

Lavender and bellbird Creek Flood Study, Patterson Britton and Partners (January 2005)[(1)]

Patterson Britton and Partners were engaged by Cessnock City Council to examine the flood behaviour along Lavender and Bellbird Creek. The aim of the *Lavender and Bellbird Creeks*

Flood Study[1] was to produce information on flood flows, velocities, levels and flood extents, for a range of flood events under existing floodplain and catchment conditions, and to highlight those areas where the greatest flood damage is likely to occur. In particular, the study provided a baseline definition of flood characteristics along Lavender and Bellbird Creeks. The study involved the establishment and calibration of hydrologic and flood hydraulic models.

Henry Kendal Limestone Creek Retirement Village – Site Flood Assessment , Patterson Britton and Partners (February 2003)[2]

In 2003, Patterson Britton and Partners were engaged by the Henry Kendall Group to examine the flooding and stormwater constraints for land owned by the Henry Kendall Group*,* which is located in the central section of the North Bellbird study area. The resulting investigations involved hydrologic, hydraulic and water quality modelling, from which predicted flood behaviour and preliminary stormwater management control requirements were established. Additionally, the investigation made broad recommendations for the rehabilitation of the lower section of Limestone Creek.

North Bellbird Investigation Area, Flooding and Stormwater Assessment, Parsons Brinkerhoff (May 2006)[3]

In May 2006, Parsons Brinkerhoff were engaged by Johnson Property Group to examine the flooding and stormwater constraints for the North Bellbird proposed residential subdivision site. The resulting examination involved hydrologic, hydraulic and water quality modelling, from which predicted flood extents and preliminary stormwater management control requirements were established.

1.5 RELEVANT LEGISLATION

The following guidelines and legislative requirements have been identified as being relevant to this investigation.

Australian Rainfall and Runoff

Australian Rainfall and Runoff (*AR&R*) is a document published in 1987 by the *Institution of Engineers, Australia* (*IEAust*)[8]. This document has been prepared to provide designers with the best available information on design flood estimation and is widely accepted as a design guideline for all flood and stormwater related design in Australia.

Australian Runoff Quality

Australian Runoff Quality (*ARQ*) is a document published in 2005 by *IEAust*[16] which provides design guidelines for all aspect of water sensitive urban design (*WSUD*), including preventative measures, source controls, conveyance controls and end of line controls. Additionally, it provides guidance for water quality modelling as well as stormwater harvesting and re-use.

Floodplain Development Manual

The *Floodplain Development Manual* is a document published by the *New South Wales State Government* in 2005 [9]. The document details Flood Prone Land Policy which has the primary objective of reducing the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits from occupation and development of flood prone land [9].

Lower Hunter and Central Coast Regional Environmental Management Strategy

The *Lower Hunter and Central Coast Regional Environmental Management Strategy* (*LHCCREMS*)[15] was prepared by a consortium of Lower Hunter and Central Coast Councils and includes Water Sensitive Urban Design (*WSUD*) as a stormwater initiative and should be considered in the planning of new development sites.

Rivers and Foreshores Improvement Act 1948

The Rivers and Foreshores Improvement Act 1948 (*R&FI Act*)[20] applies to obtaining approval for works within the 'protected land' of a waterbody or waterways.

From 27 April 2007 a new Department of Water and Energy (DWE) was created and the Department of Natural Resources (*DNR*) and the Department of Energy, Utilities and Sustainability ceased to exist. The Department of Environment and Conservation changed its name to the Department of Environment and Climate Change (*DECC*) and undertook some functions previously managed by DNR.

It is our understanding that under the most recent changes, the *R&FI Act* will be administered by the Department of Water and Energy (*DWE*), rather than the DECC.

Part 3A of the *R&FI Act* requires a permit to be obtained prior to works being undertaken within the 'protected land' including works within the waterway or waterbody or within adjacent land 40m from the top of their banks. Each permit has conditions that are specific to the type of activity undertaken to ensure there are no adverse impacts on the riparian environment and to manage an environmentally acceptable solution.

The purpose of a Part 3A permit under the *R&FI Act* is to control activities that have the potential to cause adverse impacts such as:

- Increased erosion or siltation of watercourses or lakes;
- Bed lowering and bank collapse;
- Diverting the course of a watercourse;
- Obstructing or detrimentally affecting stream flow; and
- Ecological deterioration, leading to long term watercourse stability problems.

State Environmental Planning Policy (Building Sustainability Index: BASIX) 2004

The Building Sustainability Index (*BASIX*)[21] assesses the potential performance of new homes against a range of sustainability indices, viz Landscape, Stormwater, Water, Thermal Comfort and Energy. *BASIX* aims to reduce the environmental impact on these indices through the implementation water and energy efficiency targets for all future developments.

According to the *BASIX* requirements, residential developments must be designed and built to reduce energy and mains water consumption by 40% of an average NSW homes of the same type (*the target as of 1st July 2006*). These targets represent significant savings in water and energy use in homes.

1.6 AVAILABLE DATA

An aerial survey of the study area was provided in electronic format by *Surdevel Surveyors*. This information was processed using 12D CAD software to produce a digital terrain model (*DTM*) of the site. (*refer to* ***Figure 3*** *for site survey*). 12D CAD software was used to extract cross-section (*for use in a hydraulic model*) information from the DTM. Survey information obtained for the cross-sections used in the *Lavender and Bellbird Creeks Flood Study*[(1)] was also available and was adopted for modelling cross-sections of Bellbird Creek upstream and downstream of the study area.

A comparison between the aerial survey, and ground survey indicated a reasonable correlation between the two representations of the topography. The only exception being the ground surveyed cross sections along Bellbird Creek which in some areas indicated a deeper channel than the aerial survey. It was assumed the that ground survey was more accurate and the hydraulic model cross-sections created from the aerial survey data were modified slightly to incorporate the deeper channel in some areas. Recent ground survey information of the Limestone Creek corridor indicated the aerial survey of the Limestone Creek by Bannister & Hunter Surveyors (*June 2007*) was a very good match to the aerial survey used for the flood modelling. Therefore, there was no adjustment required to flood modelling in Limestone Creek, based on the accuracy of the aerial survey.

A recent high resolution aerial photograph was also used to define existing land uses, vegetation cover and creek alignments.

Site investigations consisting of a site walk over identified hydrologic catchment parameters as well as hydraulic model parameters and identified requirements for farm dam and creek rehabilitation works.

2 CATCHMENT FEATURES

2.1 CATCHMENT DESCRIPTION

The subject study area is traversed by three major water courses. These are Lavender, Bellbird and Limestone Creeks. Each is fed by an array of smaller tributaries and ephemeral watercourses. **Figure 4** indicates the location of the study area in relation to the catchments of these water courses which cover a combined area of about 3000 ha. As shown in **Figure 4**, they extend to the south-west of the urban and commercial areas of Cessnock. Bellbird, Limestone and Lavender Creeks rise in the foothills of the Broken Back Range which reaches a maximum elevation of 483 metres above sea level at Mount Bright. In contrast, the typical floodplain elevation at the catchment outlet to Black Creek is only 65 metres above sea level.

A description of the major streams and catchment areas is presented in the following sections.

2.1.1 Lavender Creek Catchment

The Lavender Creek catchment has its headwaters on the eastern slopes of the Broken Back Range about 5 kilometres west of Cessnock at Jackson's Hill (*215 m above sea level*) (*refer to* **Figure 4**). The topography transitions from relatively steep terrain in the west to a flat open floodplain in the east. The upper catchment is characterised by rolling hills with occasional pockets of open eucalypt forest, vineyards and orchards. The lower catchment below Cessnock Golf Course was developed for residential land uses in the 1930's and the majority of the floodplain has been used for housing.

Lavender Creek is the primary drainage path through the catchment. It is an ephemeral stream that is fed by up to six smaller watercourses in the upper catchment (*refer to* **Figure 4**).

Runoff from the upper catchment discharges to an on-line detention basin that also serves as a sporting field (*refer to* **Figure 4**). Downstream of the detention basin, the creek discharges across Mount View Road via eight 1500 mm by 1500 mm reinforced concrete box culverts. Below the culvert crossing, the creek is an earth lined channel and travels through *The Oaks* Golf Course.

Beyond the golf course, Lavender Creek is a trapezoidal shaped concrete lined channel. It passes through the north-western suburbs of Cessnock before discharging into Bellbird Creek near Wade Street (*refer to* **Figure 4**).

2.1.2 Limestone Creek Catchment

The Limestone Creek catchment has its headwaters in the Broken Back Range at an elevation of about 450 metres above sea level. The upper catchment is covered by dense eucalypt forests and is characterised by very steep topography. The central and lower sections of the catchment are mostly cleared and are generally used for viticulture, orchards and grazing.

The lower section of Limestone Creek traverse through the study area (*refer to the site survey, **Figure 3***). The surrounding are is relatively flat and is characterised by cleared paddocks with occasional pockets of open eucalypt forest.

Limestone Creek is a natural ephemeral stream that is fed by five tributaries that all drain from the eastern side of the Broken Back Range. Limestone Creek joins Bellbird Creek near the northern boundary of the study area (*in the vicinity of Macquarie Street, West Cessnock*).

2.1.3 Bellbird Creek Catchment

Bellbird Creek drains the southern end of the Broken Back Range and land within Aberdare State Forest. The upper catchment is moderately steep and is covered by relatively dense eucalypt forest.

Pelton Colliery is located at the southern end of the catchment (*refer to* **Figure 4**). It comprises numerous mine water dams which are believed to temporarily store runoff during floods. Related facilities such as sediment and dirty water storages have altered the natural runoff processes from this section of the catchment. The nearby South Maitland and Pelton Colliery Railways also influence runoff patterns, having the potential to impound runoff from the most south-easterly section of the catchment.

Notwithstanding, the lower catchment is generally characterised by cleared paddocks and the urban centres of Bellbird, Bellbird Heights, and West Cessnock. As shown in **Figure 4**, urban development has extended south from Cessnock along Wollombi Road, which runs approximately parallel with Bellbird Creek. As a result, much of the urban development in the vicinity of Bellbird is located on the floodplain adjacent to the creek. The proposed North Bellbird development is also partially located on the Bellbird Floodplain adjacent the existing Bellbird township.

Bellbird Creek is the primary drainage path through the catchment. In its upper reaches, Bellbird Creek is a natural earth-lined channel. However the creek channel has been concrete lined downstream of Desmond Street (*near Cessnock Showground*).

2.1.4 Future Development Prospects

It is important to consider the cumulative impact of development when undertaking a flood impact assessment. With reference to **Figure 4,** and the above catchment descriptions, it is noted that the majority of the Limestone and Bellbird catchment areas upstream of the site are currently utilised as vineyards, collieries or State Forest. Additionally, much of this land consists of steep topography with grades exceeding 20% in some places. Hence, when considering the current land uses and the topographical constraints, it is likely that there would <u>not</u> be significant future residential development in the areas upstream of the proposed development.

However, the lower section of the Lavender Creek catchment consists of a flat open floodplain which could be potentially developed in the future.

Regardless, any future development in the catchment would need to assess the potential for downstream flood impacts.

2.2 BRIDGE CROSSINGS

A number of road bridge and culvert structures are located across Bellbird Creek. Most of these crossings are timber bridges, although some crossings are provided by reinforced concrete box and pipe culverts. Survey information of these bridge crossings obtained for the *Lavender and Bellbird Creeks Flood Study* [(1)] have been adopted for this study.

3 HYDROLOGY

3.1 PREVIOUS HYDROLOGIC ASSESSMENTS

As discussed in **Section 1.4,** hydrologic assessment of the Bellbird, Limestone and Lavender Creek catchments was undertaken as part of the following studies:

- Lavender and Bellbird Creek Flood Study, Patterson Britton and Partners (January 2005)[(1)];
- Henry Kendal Limestone Creek Retirement Village – Site Flood Assessment , Patterson Britton and Partners (February 2003) [(2)]; and
- North Bellbird Investigation Area, Flooding and Stormwater Assessment, Parsons Brinkerhoff (May 2006) [(3)].

Each of these studies incorporated hydrologic modelling, using *RAFTS* software to predict runoff hydrographs resulting from various rainfall scenarios. The *Lavender and Bellbird Creeks Flood Study*[(1)] involved a rigorous assessment of all available data which included rainfall and stream gauging which was used for calibrating the *RAFTS* hydrologic model. The *Limestone Creek Retirement village – Site Flood Assessment*[(2)] involved the refinement of the *RAFTS* model developed for the *Lavender and Bellbird Creeks Flood Study*[(1)]. Parsons Brinkerhoff created a independent *RAFTS* model for the flooding and stormwater assessment undertaken in 2006. This *RAFTS* model was roughly calibrated to the Patterson Britton results.

3.2 RAFTS HYDROLOGIC MODEL

The Runoff Analysis and Flow Training Simulation (*RAFTS*) software package was employed to quantify flood discharges from the Lavender, Limestone and Bellbird Creek catchments. *RAFTS* is a deterministic runoff routing model that simulates catchment runoff processes. It is recognised in *'Australian Rainfall and Runoff* (*AR&R 1987*)[(8)], as one of the available tools for use in flood routing within Australian catchments.

RAFTS was chosen for this investigation because it has the following attributes:

- it can account for spatial and temporal variations in storm rainfalls across a catchment;
- it can accommodate variations in catchment characteristics;
- it can accommodate stormwater controls such as detention basins; and
- it can be used to estimate discharge hydrographs at any location within a catchment.

3.3 DEVELOPMENT OF HYDROLOGIC MODEL

The *RAFTS* model developed for the *Lavender and Bellbird Creeks Flood Study*[(1)] was adopted as the 'base' hydrologic model for this study. As this model was primarily developed to assess the hydrology in the Cessnock township, a higher subcatchment resolution was required over the study area. Furthermore, higher quality of information made available from the aerial survey (*previously the subcatchments were delineated based on 10 metre contour information*) allowed for a more accurate delineation of subcatchment boundaries over the site.

The hydrologic results from the refined *RAFTS* model were used for the following aspects of this study:

- To predict peak flows and storm hydrographs for a range of storm durations and average recurrence intervals (*ARI*) at locations within the study area, these results were used for hydraulic modelling used to assess the flood behaviour over the site;
- To assess the impact of the proposed development on the hydrologic regime at locations both within and external to the study area; and
- To develop strategies to mitigate any adverse impacts to the hydrologic regime at locations within and external to the study area as a result of the proposed development.

To allow for a comprehensive impact assessment, a pre and post-development *RAFTS* model was established. Details of subcatchment delineation, adopted model parameters and key model results are present in the following sections.

3.3.1 Rainfall Loss Model

In a typical rainfall event, not all of the rainfall that falls onto the catchment is converted to runoff. Depending on the prevailing "wetness conditions" of the catchment at the commencement of the storm (*i.e., the antecedent wetness conditions*), some of the rainfall may be lost to the groundwater system through infiltration into the soil, or may be intercepted by vegetation and stored. This component of the overall rainfall is considered to be "lost" from the system and does not contribute to the catchment runoff.

To account for rainfall losses of this nature, a rainfall loss model can be incorporated within the *RAFTS* hydrologic model. For this study, the *Initial-Continuing Loss Model* was used to simulate rainfall losses across the catchment. This model assumes that a specified amount of rainfall (*e.g., 10 mm*) is lost from the system to simulate initial catchment wetting when no runoff is produced, and that further losses occur at a specified rate per hour (*eg., 1.5 mm/hr*). These further losses are referred to as continuing losses. They aim to account for infiltration once the catchment is saturated.

Both the initial and continuing losses are effectively deducted from the total rainfall over the catchment, thereby leaving the remaining rainfall to be distributed through the watershed as runoff.

As no definitive loss rate data is available for the Lavender and Bellbird Creeks catchments, rainfall loss rates used in the modelling were based on the recommended ranges outlined in the *RAFTS User Manual* (12) and documented in *AR&R 1987*(8). Calibration to a gauged rainfall/runoff event and sensitivity analyses were also undertaken to ensure that the adopted values provided reliable estimates of peak flood discharges. This is further discussed in later parts of this chapter.

3.3.2 Adopted Model Structure

The *RAFTS* model was developed based on the physical aspects of the catchment including catchment area, slope, percentage impervious area and surface roughness. This section discusses the adopted subcatchment configurations for both the existing state and developed state *RAFTS* models. **Figure 4** delineates the extent of the hydrologic assessment and indicates the catchment extents of Lavender, Limestone and Bellbird Creeks.

The catchments of Lavender, Limestone and Bellbird Creeks were divided into sub-catchments differentiated on the basis of the alignment of major tributary flow paths and watershed boundaries, as well as the homogeneity of land-use, vegetation and ground slope. Parameters such as catchment area, slope, and percentage impervious area were established from the available data and were assigned to each sub-catchment.

Catchment break-up was also designed so that the downstream points of sub-catchments draining to the lower floodplain, coincided with the likely location of inflow points for the proposed hydraulic model.

Existing State Model

The adopted subcatchment configuration for the existing state *RAFTS* model is presented in **Figure 5.** As shown in **Figure 5,** the subcatchment configuration from previous Patterson Britton models (*refer to **Figure 8** from the Lavender and Bellbird Creeks Flood Study*(1) *for previous subcatchment arrangement*) was adopted for areas external to the site. A finer subcatchment arrangement was applied over the study area to provide higher resolution of the model results. Importantly, a significant portion (*approximately 70 ha*) of the western section of the study area (*identified as subcatchments 15.00, 15.01 and 15.02 in **Figure 5***) has been identified as draining towards Bellbird Creek (*previous Patterson Britton & Partners studies assumed this area drained towards Limestone Creek*). Therefore, the subcatchment re-alignment has resulted in an increase in predicted peak flows in Bellbird Creek and a reduction of peak flows in Limestone Creek when compared to previous hydrologic models.

Developed State

The proposed urban development of the study area would introduce a significant area of impervious surfaces as well as significantly increased stormwater conveyance ‘efficiency’ resulting in a reduction in the catchment time of concentration from the existing state conditions, as well as increased runoff volumes.

In order to accurately determine the runoff hydrographs from developed areas, it is important that development areas be modelled separately from the creek systems. Hence, further delineation of the existing subcatchment arrangement was required to isolate development areas from non-development areas. The resulting developed state *RAFTS* subcatchment configuration is presented in **Figure 6.** The isolation of the development areas allows for an accurate estimation of the detention storage requirements allowing for the modelling of the downstream effects of various detention storage configurations.

In some cases, the natural topography and development layout create an unavoidable scenario where runoff from upstream non-developed land must pass through the site. For this study, it was assumed that this runoff from upstream areas would supplement the urban runoff from the developed catchment. This was accounted for in the *RAFTS* model as well any affected detention calculations.

3.4 MODEL CALIBRATION

Once the subcatchment delineation was complete, rainfall runoff parameters such as initial and continuing losses, impervious area percentages, subcatchment roughness and subcatchment lag times required adjustment. As these parameters are defined by the physical properties of the catchment, survey information and aerial photographs were used to initially estimate these parameters.

The estimated rainfall runoff parameters were then adjusted so that the rainfall runoff model emulated the gauged catchment response to an observed rainfall event. Similarly to the *Lavender and Bellbird Creeks Flood Study* [(1)], the *February 1990* flood event was adopted for calibration purposes. Available calibration data included hourly rainfall data from four rainfall gauges (*refer to **Figure 4** for rain gauge location*) within the catchment, as well as stream gauging data from Bellbird and Lavender Creeks. Refer to *Lavender and Bellbird Creeks Flood Study* [(1)] for a detailed analysis of all available calibration data.

It is noted that the *February 1990* calibration event occurred after a number of days of significant rainfall. Hence, the catchment would have been saturated prior to the calibration event occurring. In order to achieve the best possible calibration, the initial loss for pervious surfaces was reduced to 5mm to account for the antecedent conditions. However, as one of the key components of this study is to assess the impact of development on the hydrologic regime within the catchment, the initial loss for pervious surfaces was revised to 15mm for all design storm simulations (*typical for non-saturated vegetated surfaces*). This assumption is considered conservative as it would result in a greater difference between pre and post development total peak flows and runoff volumes.

Table 3-1 presents the range of hydrologic parameters adopted for various subcatchment land uses. A detailed list of all individual subcatchment parameters is contained in **Appendix A**.

Table 3-1 – Existing State *RAFTS* parameters

Existing Urban Catchments		
	Impervious Surfaces	**Pervious Surfaces**
Initial Loss (mm)	1.5	15
Continuing Loss rate (mm/hr)	0	2.5 – 4.5
Catchment Roughness	0.025	0.05 – 0.12
Undeveloped Catchments		
	Rural Catchments	**Forested Catchments**
Initial Loss (mm)	15	15
Continuing Loss rate (mm/hr)	2.5 – 4.5	2.5 – 4.5
Catchment Roughness	0.05 - 0.12	0.07 - 0.12

Subcatchment lag times were estimated based on average channel gradient and longitudinal channel distance. Some lag times were adjusted to improve the calibration. The estimated lag times over the study area were compared to the conveyance times derived from channel velocities predicted by the hydraulic model, and were found to be adequate. All subcatchment lag times are presented in **Appendix A.**

Figure 7 provides a plot of the modelled versus gauged hydrographs for the *February 1990* calibration event. As show in **Figure 7,** an excellent 'fit' was achieved between the model results and the observed stream gauging.

Rainfall runoff parameters over the study area were adjusted to reflect the alterations to the catchment resulting from the proposed urban development. As previously mentioned, the developed state model involved further delineation of the existing state subcatchments over the study area. This effectively isolated development areas from areas proposed to remain in an existing (*or rehabilitated)* state. Accordingly, rainfall runoff parameters for the development areas were adjusted to represent the modified physical attributes of an urban catchment**. Table 3-2** defines the rainfall runoff parameters adopted for the developed state *RAFTS* model. A detailed list of individual subcatchment parameters is contained in **Appendix A.**

Table 3-2 - Developed State RAFTS Parameters

	Impervious Surfaces	Pervious Surfaces - Urban Catchment
Initial Loss (mm)	1.5	15
Continuing Loss rate (mm/hr)	0	2.5
Catchment Roughness	0.015	0.035

3.5 DESIGN STORM ESTIMATION

The calibrated *RAFTS* model was used to predict existing and developed state runoff hydrographs at all *RAFTS* nodes in the modelled catchment. Refer to **Figure 5** for *RAFTS* node locations. Analysis of a full range of design storm events was undertaken. The 540 min (*9 hour*) design storm was predicted to be the critical storm duration at the downstream end (*south western extent of Cessnock township*) for the catchment for all return periods. This was consistent with the findings in previous studies.

Peak flow predictions for both the existing and developed state models are presented in **Table 3-3** below. Peaks flow predictions at the downstream end of Limestone Creek (*RAFTS node 20.09*), Lavender Creek (*RAFTS node 1.04*) and Bellbird Creek (*RAFTS node 10.06*) as well as at the confluences of Bellbird and Limestone Creek (*RAFTS node 10.07*); and Bellbird Creek with Black Creek (*RAFTS node Outfall)* were selected for presentation in **Table 3-3**.

To allow for comparison of results, peak flows from the existing state and developed state models are shown concurrently with peak flows published in previous studies undertaken by Patterson Britton & Partners [(1)] and Parsons Brinkerhoff [(3)]. In order to simplify the reporting, only peak flows for the 2yr, 5yr, 20yr, 100yr and 500yr models are presented in **Table 3-3.** Refer to **Appendix B** for model results over a full range of storm durations and all simulated ARIs.

Table 3-3 – Design Storm Hydrology results.

Rafts Model Node ID	Storm Event	Existing State Model		Developed State Model		Pat Brit Previous[(1)]	Parsons Brinkerhoff Existing State[(3)]	Parson Brinkerhoff Developed State[(3)]
		Peak Discharge (m^3/s)	Total Runoff Volume (ML)*	Peak Discharge (m^3/s)	Total Runoff Volume (ML)*	Peak Discharge (m^3/s)	Peak Discharge (m^3/s)	Peak Discharge (m^3/s)
Bellbird Creek (10.06)	2 yr	23	366	23	410	-	-	-
	5 yr	33	533	33	583	33	-	-
	20 yr	49	776	48	830	46	-	-
	100 yr	67	1119	65	1178	63	-	-
	500 yr	88	1486	86	1547	-	-	-
Limestone Creek (20.09)	2 yr	26	332	27	372	-	-	-
	5 yr	39	479	39	525	39	-	-
	20 yr	56	692	55	740	56	-	-
	100 yr	75	990	73	1043	76	-	-
	500 yr	98	1308	95	1364	-	-	-
Lavender Creek (1.04)	2 yr	10	114	10	116	-	-	-
	5 yr	14	160	14	162	13	-	-
	20 yr	18	222	18	224	17	-	-
	100 yr	23	307	23	308	21.1	-	-
	500 yr	30	396	29	397	-	-	-
Confluence of Bellbird and Limestone Creek (10.07)	2 yr	49	712	50	797	-	-	-
	5 yr	73	1032	72	1128	73	75	72
	20 yr	106	1495	104	1598	104	115	110
	100 yr	143	2148	140	2260	141	162	155
	500 yr	188	2843	183	2961	-	-	-
Confluence of Bellbird and Black Creek (Outfall)	2 yr	59	944	60	1036	-	-	-
	5 yr	85	1355	85	1457	87	80	76
	20 yr	122	1918	120	2029	122	121	116
	100 yr	163	2684	160	2804	164	170	163
	500 yr	212	3494	208	3619	-	-	-

* Note: Total volume of the runoff hydrograph calculated from the first 15 hours of runoff from the start of rainfall

As show in **Table 3-3,** the predicted existing state peak flows were similar to the previous Patterson Britton results. Parsons Brinkerhoff *RAFTS* results[(3)] were only available at the confluence of Bellbird and Limestone Creeks (*RAFTS node 10.07*) and were between 5 and 15% greater than the previous Patterson Britton results[(1)] and the current estimates. This variation is typical for models of this scale and is most likely due to slight variations in the subcatchment arrangement and model calibration.

Results in **Table 3-3** indicate that the introduction of the proposed urbanisation through-out the study area would <u>not</u> result in an increase in peak flows during any significant flood events (*defined as all events including and greater than 5 year ARI*). In fact, a slight reduction in peak flows was predicted. As shown in **Table 3-3,** modelling undertaken by Parsons Brinkerhoff [3] also predicted a similar result. This phenomenon is the result of increased efficiency of the urban drainage (*modelled as a reduced catchment roughness and reduced rainfall losses*) in the study area. As the study area is at the downstream end of the overall catchment, the reduced time of concentration of the urban catchments allows a greater proportion of runoff from the urban catchments to 'escape' prior to runoff arriving from the upper extents of the catchment. This is further discussed in subsequent sections.

While modelling indicates that the introduction of urban development to the study area would result in a reduction in peak flow, it is noted that total runoff volume would increase slightly. This is the direct result of the application of impervious surfaces, which eliminate infiltration losses typically observed over pervious areas. Results presented in **Table 3-3** indicate that the proposed development would increase the total runoff volume at the confluence of Bellbird and Limestone Creeks by approximately 5% (*for the 9 hour 100 year ARI design critical duration storm*). The effect of this increase on peak flood levels downstream would be expected to be negligible, particularly given there is a net reduction in the estimated post development peak flow at this location. Although there is no predicted downstream impact of the slight runoff volume change, we note under **Section 3.11,** that works are proposed as part of the stormwater management strategy to address the predicted minor increase in runoff volume from the development, in accordance with best management practice.

3.6 PARTIAL AREA STORM ESTIMATION

Rainfall runoff scenarios were also modelled to assess the effect of the proposed development during a rainfall event central to the study area (*i.e. a "partial area" storm*). The area assessed for the partial area storm is indicated by the site boundary line in **Figure 4.** By excluding the runoff from upstream catchment areas, the runoff hydrographs from the study area can be isolated allowing for the effect of the a localised "partial area" storm on the lower portion of the catchment to be compared to a "total catchment" area storm.

Figure 8 presents the predicted runoff hydrograph at the confluence of Bellbird and Limestone Creeks (*RAFTS node 10.07*) for both the "total area" and "partial area" developed and existing state simulations (*for the 9 hour 100 year ARI design critical duration storm*).

As both the partial and total area storm events used identical rainfall, the partial area hydrograph effectively represents the portion of the total area hydrograph which is produced by runoff from the study area. **Figure 8** also demonstrates why the predicted developed state peak flows in **Table 3-3** were slightly reduced from the existing state model. By inspection of the "partial area" hydrographs it is clear that the developed state hydrograph peaks approximately 30 minutes before the existing state hydrograph. This results in the partial area hydrograph being on the receding limb when the peak flow from the total hydrograph arrives at *RAFTS node 10.07*, hence the lower overall peak flow downstream of the study area.

3.7 SENSITIVITY ANALYSIS

To examine the models sensitivity to hydrograph timing, a sensitivity analysis was conducted on the following *RAFTS* model parameters:

- **Catchment link lag time.** Catchment lag times were used in the *RAFTS* model to represent the time taken for runoff to convey from one subcatchment outlet to the next downstream node. By reducing lag times, the hydrographs are 'pushed' together resulting in a higher peak flow; and

- **Imperious and Pervious area roughness**. Roughness parameter defines how quickly the subcatchment responds to rainfall, a rougher catchment over the study area would retard the runoff, hence in this case would be considered conservative as the runoff peak from the study area would occur closer to the total catchment peak.

As the *RAFTS* model developed for the *Lavender and Bellbird Creeks Flood Study* (1) was adopted as a base model, it was assumed that calibration of the model provided the most accurate rainfall runoff parameters given the available data. Hence, the sensitivity of roughness parameters was only applied to subcatchments within the study area. Adjustments to catchment lag times were applied globally over the entire catchment.

Results from the sensitivity analysis are presented in **Table 3-4.**

Table 3-4 – Results from sensitivity analysis

Scenario	Scenario Description	Catchment lagtimes (% of adopted lag times)	Impervious roughness	Pervious Roughness	Predicted Peak Flow at *RAFTS* node 10.07 for a 9 hour 100 year design storm (m^3/s)
1	Existing State : 100% lag times	100 %	Not Assessed*	Not Assessed*	143
2	Existing State : 50% lagtimes	50 %	Not Assessed*	Not Assessed*	149
3	Developed State: 100 % lag times & low roughness	100 %	0.015	0.035	140
4	Developed State: 100 % lag times & high roughness	100 %	0.025	0.05	141
5	Developed State: 50 % lag times & low roughness	50 %	0.015	0.035	147
6	Developed State: 50 % lag times & high roughness	50 %	0.025	0.05	148

* Note: Sensitivity of existing state roughness parameters not assessed as these were estimated based on the calibration of the rainfall runoff model.

With reference to **Table 3-4,** the sensitivity analysis demonstrated that the model is not overly sensitive to variations in subcatchment roughness parameters with both sensitivity Scenarios 4 and 6 predicting less than a 1% increase in peak flows when compared to the respective lower roughness scenarios. As expected, reducing catchment lag times by 50% did result in an increase in peak flow (*6m^3/s in the existing case and 7m^3/s in the developed case*). It is noted that the worst case developed state flow (S*cenario 6: increased roughness and reduced lag times*) did not exceed the reduced lag time existing state (S*cenario 2*) peak flow.

The above analysis was conducted using the design storm approach as stipulated in *AR&R (1987)*[(8)]. It is noted that the design storm approach applies uniform rainfall patterns over the entire catchment. However, it is conceivable that a rainfall event could occur where a storm cell develops in the upper extents of the catchment and progresses down the catchment. This would result in the runoff hydrographs from the upper catchment being more synchronised with the runoff from the lower catchment (*study area*), producing a ‘compressed’ hydrograph with a higher peak. While variations in rainfall intensities have not been modelled, the 50% reduced lag times sensitivity scenario would be indicative of an approximate 20 minute delay in rainfall bursts between the upper and lower catchments.

3.8 EFFECT ON FLOODING IN CESSNOCK

With reference to **Figure 8** and the predicted peak flows presented in **Table 3-3**, the following conclusions can be made regarding the effect of the proposed development on flooding in the Cessnock township:

- ❒ Modelling indicates that the proposed urban development would not increase peak flows in the Cessnock township during any of the design storms modelled over the range from 5 to 500 year ARI (*note that there is a minor increase predicted in the 2 year ARI event, ignoring proposed stormwater management controls*) ;

- ❒ Similarly, with reference to **Table 3-3**, modelling of Limestone, Lavender and Bellbird Creeks indicates that the proposed development would not increase peak flows locally through these creeks except for a minor increase in low return period events;

- ❒ Modelling of a “partial area” storm (*i.e only rainfall over the study area*) indicated that the proposed development would increase peak flows locally. However, the peak developed state 100 year ARI “partial area” flow remains less than the 5 yr ARI flow for the “total catchment”. Hence, the study area does not have sufficient area to govern flooding in Cessnock. Therefore, only total area modelling results should be used for assessing the impact of the proposed development on local and regional flooding; and

- ❒ The introduction of impervious surfaces would increase total runoff volumes by approximately 5% during a 100 year ARI critical duration storm. The effect of the increased volume on downstream flood levels is expected to be negligible, and would be partially mitigated by the appropriate selection of stormwater management controls. Consideration of the possible flood level impact downstream (*while expected to be insignificant*) could only be defined using a hydrodynamic model of the downstream watercourses. Such an approach could be undertaken at the Development Application stage, if considered necessary.

3.9 EFFECT ON FLOODING DOWNSTREAM OF CESSNOCK

As shown in **Figure 4,** the *RAFTS* model does not extend past the confluence of Bellbird and Black Creeks. Hence, the effects of urbanisation of the study area on hydrology downstream of

Cessnock is beyond the scope of this study and has not been assessed. However, it is noted that Black Creek conveys runoff approximately 30 km north before discharging into the Hunter River upstream of Maitland. As Black Creek is adjacent to Rothbury, Branxton and future residential areas such as the proposed Huntlee site (*near Braxton*), the cumulative effect of urbanisation in the Black Creek catchment should not be ignored, however, these effects are outside of the scope of this study.

Notwithstanding, the increased volume from the urban catchments on the subject site would be the most likely contributor to increased flood levels in large catchments such as Black Creek, as it increases the 'body' or volume of the runoff hydrograph. Generally, any abrupt localised increases in peak flows (*typical in runoff hydrographs from urban areas*) would be attenuated as soon as floodwaters are spread over a floodplain area. Again, we note that the expected change in flood volume generated by the development (*less than 5%)* during a 100 year ARI critical duration storm, would not be expected to have any significant measurable effect on downstream flood levels.

3.10 MITIGATION OPTIONS

Detention basins are commonly used to reduce flood peaks in catchments where peak flows are greater than existing levels. However, it is noted that detention basins only delay stormwater release, resulting in no reduction in total in runoff volume. Hence, generally urbanising a subcatchment will result in an increase in total runoff volume, regardless of whether stormwater detention is provided.

In order to assist in the alleviation of any potential increase in runoff volume from the development, an "**extended detention**" policy (*refer box description below*) has been adopted for the proposed stormwater management controls for the development (*refer* **Section 3.11** below). Again, while these controls would not totally negate any effect in volume increases, the combination of low overall increase in flood volume (*less than 5% during a 100 year storm),* the proposed stormwater management controls, and the fact that limited future development is expected in the upper catchment of Bellbird of Limestone Creeks would all combined to ensure that there was no discernable or cumulative change in the downstream flood levels in the Cessnock Township.

"**Detention**" – the principal goal of Detention is flood attenuation and peak flow reduction achieved through temporary ponding for relatively short periods. The volume of surface runoff is relatively unchanged.

"**Extended Detention**" – or "**Retention**" - is defined as a scheme whereby runoff is held for relatively longer periods to allow reductions in downstream flooding through either infiltration, evapo-traspiration, or simply by the slower release of runoff along the downstream waterways well outside of the timing of downstream flood peaks (e.g. as "baseflow").

It should also be noted that a policy such as a 100 year detention for the development areas would not have any effect in alleviating the potential increase in runoff volumes from the development.

Therefore, the following **Section 3.11** outlines our recommendations regarding a proposed stormwater management policy.

3.11 RECOMMENDED STORMWATER MANAGEMENT POLICY

Considering the hydrologic modelling results and the model sensitivity analysis, it can be concluded that implementation of detention storage across the proposed development site would provide no benefit to areas downstream and adjacent to the site during any of the flood events modelled. Hence, it is recommended that detention across the site is not required from a downstream flood mitigation point of view.

Notwithstanding, water quantity controls will be required to mitigate the effects of the altered flow regime during more frequent (*lower*) flow events (*e.g. 1-2 year ARI event*). This would minimise the downstream effects on the existing riparian corridors from a bank stability and water quality viewpoint. This is further discussed in **Section 5.** The resulting water quantity controls recommended as part of the stormwater management strategy for the study area are outlined below:

- Provide stormwater detention to reduce peak developed flows to existing state levels for all storms up to the 2 year return period;

- Provide 20 mm of “extended detention” (*refer text box above for description*) per unit of impervious areas in urban subcatchments. This can be integrated into water quality control measures such as wetlands or bio-retention areas as well as rainwater tanks. The extended detention should be designed so that it empties with in 48 hours of the cessation of rainfall; and

- Additional retention would be provided in the permanent water zone of constructed wetlands if rainfall occurs after a prolonged dry period, this has not been accounted for in hydrologic modelling.

It is noted that the recommended stormwater management controls are driven by water quality and environmental outcomes. However, the provision of “extended detention” would also have a positive effect in reducing the overall flood runoff volume from the site during lower return period events. This is discussed in the following section.

3.11.1 Modelling the effect of Stormwater Management Controls

The developed state *RAFTS* model was modified to include the stormwater management controls discussed in **Section 3.11.** These controls were modelled as detention basins in *RAFTS*. The required basin storage and stage discharge for each urban subcatchment was calculated using the *RAFTS* model. **Figure 9** compares the existing state, developed state (*with no controls*) and the developed state (*with controls*) hydrographs at the confluence of Bellbird and Limestone Creeks

(*RAFTS node 10.07*). The 100 year ARI 120 min (*2 hour*) and 540 min (*9 hour*) as well as the 2 year ARI 120 min (*2 hour*) storm duration hydrographs are presented.

As shown in **Figure 9,** the implementation of the recommended stormwater controls would effectively mitigate the effects of development (*for peak flow and runoff volume*) during a 2 year ARI 120 min storm (*which was the adopted storm for designing the controls*). For higher return periods, the stormwater management controls would become overwhelmed and would not offer complete attenuation of developed flows to existing conditions. However, the resulting increase in partial area flow (*as discussed in **Section 3.6***) is on the rising limb of the total hydrograph, hence the over-all catchment peak flow is not increased. As shown in **Table 3-5,** the implementation of the recommended stormwater management controls would result in a reduction in total runoff volume (*when compared to the developed state no-controls hydrographs*).
Table 3-5 summarises the estimated total runoff volume for the storm hydrographs presented in **Figure 9.**

Table 3-5 – Estimated Total runoff volumes

	Existing State	**Developed State (No Controls)**		**Developed State (With Controls)**	
Design Storm	Total Runoff Volume (ML)	Total Runoff Volume (ML)	Increase in total runoff volume from existing state (%)	Total Runoff Volume (ML)	Increase in total runoff volume from existing state (%)
2 year 120 min	254	300	18.1 %	250	Nil
100 year 120 min	983	1054	7.2 %	1002	1.9 %
100 year 540 min	2148	2260	5.2 %	2219	3.3 %

As shown in **Table 3-5,** the implementation of the recommended stormwater management controls would reduce the increase in total runoff volume for all storm scenarios. The reduction would be more effective (*percentage wise*) for either low return period storms (*such as the 2 year ARI*) or the shorter duration storms such as the (*100 year ARI 120 min storm*). As discussed previously, while these controls would not totally negate any effect in volume increases, the combination of low overall increase in flood volume (*less than 5%),* the proposed stormwater management controls, and the fact that limited future development is expected in the upper catchment of Bellbird of Limestone Creeks would all combined to ensure that there was no discernable or cumulative change in the downstream flood levels in the Cessnock Township.

3.12 PROBABLE MAXIMUM PRECIPITATION

Probable Maximum Precipitation (*PMP*) is defined by the World Meteorological Organisation (*1986*) [6] as *'the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year'*. Calculation of the PMP allows estimation of the Probable Maximum Flood (*PMF*), which in turn is used to determine appropriate land uses on a risk management basis.

The PMP storm was estimated using the Generalised Short Duration Method (*GDSM*) which is published by the Australian Bureau of Meteorology (*June 2003*) [(6)]. The GDSM method is suitable for storm durations of up to 6 hours. It is noted that changes to the calculation of Moisture Adjustment Factor (*MAF*) [(6)] made in December 2006 have increased the PMP as compared to those calculated previously by Patterson Britton [(1)] and Parsons Brinkerhoff [(3)].

Estimated PMP rainfall distributions were entered into the developed state *RAFTS* model to assess the resulting runoff hydrographs. The critical storm duration was found to be the 2 hour storm (*although the 2 and 2.5 hour storm had very similar peak flows in all catchments*). Predicted peak flows at the confluence of Bellbird and Black Creeks are presented in **Table 3-6.** Full detail of the PMP calculations can be found in **Appendix C**.

Table 3-6 – Peak Discharge Estimate for Probable Maximum Flood (PMF)

Location	Patterson Britton PMF Peak Discharge Estimate (m^3/s) Feb 2003	Parsons Brinkerhoff PMF Peak Discharge Estimate (m^3/s) May 2006	Patterson Britton PMF Peak Discharge Estimate (m^3/s) July / 2007
Confluence of Black and Bellbird Creeks (*RAFTS node 'outfall'*)	1149	1156	1210

N.B. Changes were made to the PMP calculation methodology by the BoM (June 2003) [(6)] after the preparation of the original PatBrit report, resulting in an increase in calculated PMP values.

As shown in **Table 3-6** estimated peak flows during a PMF event over the site are similar to those previously calculated by Patterson Britton and Parsons Brinkerhoff. The differences relate to the changes to the PMP estimation guideline by the BoM [(6)].

4 FLOODING ASSESSMENT

The Cessnock area has an established history of flooding, with numerous well document flood events occurring over the last 50 years. Accordingly, a flood assessment is required as part of the planning for the proposed residential development of the study area. This section discusses the flooding aspects of the site with a careful analysis of the both the suitability of land within the study area for development and an analysis of the effects of the development on flood behaviour both internally and external to the site.

A flood hydraulic model was created to assess various flood events over the site. The hydraulic model applied hydrologic results from the *RAFTS* model established for this study (*refer to **Section 3***). Hydraulic model results were interpreted to define the estimated flood behaviour and extent of inundation over the site, allowing for the hydraulic categorisation of flood affected areas and identification of high and low hazard areas. This information was then used to define planning criteria for the proposed development in accordance with the requirements of the *Floodplain Development Manual (NSW Government, 2005)* [9].

4.1 DISCUSSION

The proposed development area is located at the downstream end of the approximate 30 square kilometres catchments of Limestone, Bellbird and Lavender Creeks. Analysis of the hydrology of these catchments is discussed in **Section 3.** Hence, the resulting flood behaviour over the site must be carefully assessed to ensure the appropriate planning controls are implemented.

Proposed development areas in the north eastern corner of the site are located within the Bellbird Creek floodplain. Therefore, a careful assessment of flood levels is required to assign appropriate planning controls to meet the requirements of the *Floodplain Development Manual* [9]. Furthermore, numerous existing residential dwellings are located immediately adjacent to the eastern bank of Bellbird Creek. As many of these properties are potentially flood affected, it is imperative that proposed development does not increase flood risk to existing properties.

With reference to **Figure 3,** it is noted that Bellbird and Limestone Creeks are essentially aligned parallel to each other. Limestone Creek has an average channel gradient ranging between 0.4% to 0.8%, while Bellbird Creek is flatter, observing an approximate gradient of 0.35% on average. As land between these creeks grades gently towards Bellbird Creek (*i.e. there is no ridge separating the creeks*) any flooding in Limestone Creek which exceeds the channel capacity would overflow into the Bellbird Creek floodplain. As residential development is proposed in the area between Bellbird and Limestone Creeks, the frequency of occurrence and resulting implications of Limestone Creek overtopping must be carefully assessed.

Accordingly, a hydraulic model was developed to assess the flood behaviour over the site. The model and the results are discussed in subsequent sections.

4.2 HYDRAULIC MODEL DEVELOPMENT

4.2.1 HEC-RAS Model

The HEC-RAS software package was used to develop a hydraulic model of the Bellbird, Limestone and Lavender Creek systems.

HEC-RAS is an integrated software package designed to enable one-dimensional river modelling using steady-flow, based on a single geometric representation of the stream network. It is the successor to the steady-flow *HEC-2 Water Surface Profiles* software, which has been used widely to simulate flood behaviour in river and channel systems, particularly where structures constrain free surface flow.

In its simplest application (*steady-flow simulations*), it automates the well known and respected *Standard Step Method* for backwater analysis.

The HEC-RAS software was originally developed by the US Army Corp of Engineers. The program enables bridges and culverts to be modelled using the physical dimensions of the structures. This makes it particularly useful for the Limestone/Bellbird system which requires the modelling of numerous existing and proposed bridges and culverts.

4.2.2 Survey Data

A hydraulic model is based on the topographic representation of the stream and its floodplain. Therefore, the topographic survey data gathered provided (*refer to **Section 1.6***) was compiled to assess its usefulness for development of the hydraulic model.

As discussed in **Section 1.6,** survey data from the aerial survey, ground survey of the Limestone Creek corridor and cross-section surveys (*of Bellbird and Lower Limestone Creeks only*) undertaken for previous flood studies was utilised. Additionally, a recent high resolution aerial photograph of the site was also used. This data was assessed in conjunction with a series of site inspections to determine the most suitable locations for cross-sections extracted for the hydraulic model.

As the aerial survey was only available over the study area, the previous Patterson Britton model(1) of Bellbird Creek was appended upstream and downstream of the study area boundary. As discussed in **Section 1.6**, a comparison between the aerial survey and ground survey data of Bellbird Creek indicated that the aerial survey estimated the channel being approximately 1 metre shallower than the ground survey. It was assumed that the ground survey was more accurate so the deeper channel invert was adopted ins some locations for Bellbird Creek. A similar comparison between aerial and ground survey was undertaken for Limestone Creek, which showed that there was much less discrepancy in this case. This is probably because of the lack of significant vegetation along Limestone Creek. The addition of ground survey data to the aerial survey gave a reasonably high degree is surety regarding the flood modelling undertaken.

This flood assessment required the development of the following HEC-RAS models:

- **Existing State Model**: Created to assess the existing flood behaviour over the site. The model included existing bridges and culverts located along Bellbird Creek. The bridge and culvert hydraulic properties were sourced from the existing Patterson Britton model.

- **Developed State Model**: Modifications to the existing state model to include proposed bridges, creek modifications and filling. Cross section locations for the developed state model are presented in **Figure 10.**

- **PMF Model:** As the PMF flood inundates the north-eastern section of the study area, Limestone and Bellbird Creeks effectively act as a common channel. Hence, the cross section configuration adopted for the existing and developed state scenarios was modified to reflect this. Cross section locations for the PMF model are presented in **Figure 11.**

4.2.3 Channel and Floodplain Roughness

Channel and overbank roughness was determined for each model cross-section based on vegetation densities observed through field observations and inspection of the aerial photographs. Manning's 'n' values were conservatively adopted based on standard guidelines for channel types and vegetation density outlined in literature (*refer to Chow*) (7). **Table 4-1** lists the adopted mannings 'n' values for the various channel types and vegetation cover observed on the site. **Appendix E** details adopted roughness parameters for all model cross-sections.

Table 4-1 - Adopted Typical channel and floodplain Manning's 'n' roughness

Description	Mannings 'n'
Channel Roughness	
Very densely vegetated channel	0.1
Densely vegetated channel	0.07
Highly eroded channel	0.05
Engineered Urban Waterway	0.04
Concrete Lined Channel	0.025
Over Bank/ Floodplain Roughness	
Very densely vegetated channel	0.1
Densely vegetated channel	0.07
Grassed pasture	0.05

4.2.4 Model Boundary Conditions

Hydrologic Boundary Conditions

Peak flows extracted from *RAFTS* results (*refer to* ***Section 3***) were applied to the steady state hydraulic analysis. Predicted flows were applied to HEC-RAS cross-sections aligned at the upstream boundary of the corresponding subcatchment. **Appendix D** presents all flows applied to model cross-sections for all modelled flood scenarios.

Hydraulic Boundary Conditions

Downstream boundary conditions for Bellbird and Lavender Creeks were extracted from the existing Patterson Britton HEC-RAS model of Limestone and Bellbird Creeks, refer to *Lavender and Bellbird Creeks Flood Study)* [1].

Upstream boundary conditions were assumed to be at normal depth and were assigned based on the estimated channel bed slope.

Refer to **Appendix D** for adopted boundary conditions.

4.3 DESIGN FLOOD ESTIMATION

4.3.1 Design Simulations

The HEC-RAS model developed for Bellbird, Limestone and Lavender Creeks was used to simulate flood behaviour for the full range of design events, including the Probable Maximum Flood. Results from the 20, 100, 500 year ARI design floods as well as the PMF were selected for presentation in this report. Hydraulic modelling was undertaken for both the exiting state and developed state scenarios, allowing for the assessment of the impact of the development on flood behaviour.

4.3.2 Model Results

The results of the hydraulic modelling are listed in detail in **Appendix F**. Floodwater surface profiles are presented in **Figure 12** through to **Figure 17.** Model results were also compiled with the survey data used to develop the HEC-RAS model. This information was used to generate flood extent maps across the study area. **Figure 18** through to **Figure 22** present the estimated flood extents for the 20 year ARI, 100 year ARI an PMF events.

4.4 HYDRAULIC CATEGORISATION OF FLOODWAY AREAS

Hydraulic categorisation to define Floodway areas was undertaken to locate the key flood conveyance areas of the site. Floodway extents over the site were defined using the floodplain encroachment method in HEC-RAS, which assesses the sensitivity of the floodplain to loss of flow area through reducing the floodplain width. Generally, the reduction of flow area results in an increase in flood water level. Hence, the Floodway areas were established by allowing encroachment so that a maximum resulting water level increase of 100mm was achieved during the 100 year ARI design flood [9]. The resulting encroachment locations were used to define the Floodways over the site.

Estimated Floodway areas are detailed in **Figure 18** through to **Figure 22.**

4.5 IMPACT OF THE PROPOSED DEVELOPMENT ON LOCAL AND DOWNSTREAM FLOODING

4.5.1 Ground Level Modifications

It is recommended that the 100 year flood level be adopted as the Flood Planning Level. The following modifications to the flood affected land would be required as part of the urban development:

- ❒ Modifying the natural ground surface in residential areas so that floor levels of dwellings are at least 500 mm above the predicted 100 year flood level;
- ❒ Construction (or modification) of bridges across the site; and
- ❒ Construction of stormwater infrastructure such as constructed wetlands / retention basins with in the 100 year flood extent.

Figure 24 indicates the extent of proposed ground level modification and location of proposed bridges and constructed wetlands / retention basins. It is noted that all ground level modifications and constructed wetlands are outside of areas designated as Floodway, hence it is assumed that they would have a negligible effect on flood conveyance (*and therefore no increase in upstream or adjacent flood levels*).

In some locations, ground surface modifications are proposed within the 100 year ARI flood extent, but outside of Floodway area (i.e. Flood Fringe / Flood Storage areas). This would result in a slight reduction of overall flood storage. However, an examination of the proposed filled areas indicated that the total area of proposed filling inside the 100 year flood extent was approximately 9.1 hectares. This is less than 10% of the estimated 96.1 hectare 100 year flood extent. As shown in **Figure 24**, all proposed fill locations are on the fringe of the 100 year flood extent, indicating there would be no significant loss in flood storage. Hence, the effect on downstream flood levels is not expected to be significant, however, it can not be fully assessed without using a hydrodynamic model.

4.5.2 Proposed Bridges

As all proposed bridges are required to traverse land categorised as Floodway, the effect of the bridges on the local hydraulics was assessed in HEC-RAS. The assessment considered the effect of increasing flood levels on both existing properties adjacent to the site as well as implications on future development within the site. Minimum waterway areas for each bridge were developed based on the hydraulic assessment. These conceptual bridge configurations suggest bridge design guidelines such as minimum waterway area, deck levels, number of piers and allowed extent of filling for abutments. Flow area restrictions of 300mm and 500mm were applied to columns and deck soffits respectively to account for potential debris blockage during a flood event. Minimum hydraulic waterway areas for each of the proposed bridges as well as the predicted 100 year ARI flood existing and developed (*i.e. with bridge*) state flood levels are presented in **Figure 25** through to **Figure 27**.

It is proposed to upgrade the existing Abbotsford Street Bridge, which spans Bellbird Creek just to the east of the site. Currently the bridge deck intrudes into the floodway. As there are a number of dwellings immediately upstream from the bridge, it is expected that the existing bridge configuration would be a serious constriction to flood flows, and would currently affect the flood hazard and extent of property damage during a flood event along Bellbird Creek. The upgrading of Abbotsford Street bridge provides an opportunity to improve the hydraulic efficiency of the road crossing and to potentially reduce flood levels within existing properties adjacent to the proposed development. The concept bridge option detailed in **Figure 27** would incorporate a raised bridge deck and an expanded channel width. Modelling indicates that this would result in a 500mm reduction in upstream 100 year ARI flood levels.

4.5.3 Discussion of Hydraulic Model Results

The HEC-RAS results were compared to results from previous studies undertaken by Patterson Britton (2) and Parsons Brinkerhoff (3). Comparison of predicted 100 year ARI peak water surface elevations are provided in **Table 4-2**. It is noted that the comparison of results in **Table 4-2** are from three different models, which incorporated independent cross-section arrangements. Hence, absolute comparison of the flood results is not possible as the cross-sections in the three different models may not exactly represent the same location along a creek system.

Table 4-2 – Comparison of HEC-RAS Results

Cross Section Chainage	Previous Patterson Britton (1)		Parsons Brinkerhoff (3)		This Study	
	Cross Section ID	Peak 100 Year Flood Level (mAHD)	Cross Section ID	Peak 100 Year Flood Level (mAHD)	Cross Section ID	Peak 100 Year Flood Level (mAHD)
Lavender Creek						
CH 513	NA	NA	12-333.13	85.74	0-20-513	85.84
Limestone Creek						
CH 1571	NA	NA	4-1571	86.27	4-998-1585	86.53
CH 2129	NA	NA	4-2085	88.29	4-998-2129	88.89
Bellbird Creek						
CH 1577	B 49	80.90	1-1164	81.11	1-1577-1577	81.03
CH 1811	B.50	81.13	1-1322	81.45	1-1577-1811	81.24
CH 3035	B 54	86.6	1-2570	86.54	1-1577-3035	86.68
CH 3836	B 57	89.23	NA	NA	1-3412-3836	89.33
CH 4135	B58	90.1	NA	NA	1-3412-4135	91.18

As shown in **Table 4-2**, there is some variation between model results. Predicted flood levels along Lower Limestone Creek (*CH 1577 to CH 3035*) were reasonably consistent between the three models. However, peak flood level predictions between the current model and previous Patterson Britton [(2)] results were significantly different at the Abbotsford Street Bridge (*water levels taken at the downstream end of the bridge in both models*). This is believed to be due to variations in downstream cross-section profiles and adopted 100 year peak flow rates (*resulting from variations to the subcatchment arrangements*). Only two cross-sections on Limestone creek were identified as being sufficiently aligned with the Parsons Brinkerhoff [(3)] cross-section arrangement for a suitable comparison. The more recent Patterson Britton (*this study*) water levels were both higher, this is most likely reflecting the lower channel roughness adopted by Parsons Brinkerhoff[(3)] (*0.04 compared to 0.07 in the Patterson Britton model*). As previously mentioned, the roughness in Limestone Creek was intentionally increased by Patterson Britton to represent the re-vegetated scenario.

The following sections discuss the flood results for each of the major creeks.

Lavender Creek

Figure 12 indicates predicted flood levels along Lavender Creek. As shown in **Figure 24** an estimated 1.2 ha of filling will be required to achieve the proposed development extent. This would result in a reduction in flood storage, however, as the Mount View Road Detention Basin (*which is immediately downstream of the site boundary*) acts as a control on downstream flooding in Lavender Creek, it is unlikely that the loss in flood storage would impact flood levels downstream of the site. It is noted that during a PMF, the Mount View Road Detention Basin would spill from the upstream end and flow to the south of the basin, towards the confluence of Limestone and Bellbird Creeks. This effect should be considered in the future planning of the development for the site.

Bellbird Creek

Figure 16 indicates the predicted flood levels along Bellbird Creek. As shown in **Figure 24** the proposed development along Bellbird Creek would require the filling of approximately 7 ha of land within the 100 year flood extent. It is noted that all filling is outside of the designated Floodway, hence it is unlikely that there would be any discernable effect on flood conveyance. However, the proposed filling would equate to approximately 14% of the predicted 100 year flood extent along Bellbird Creek. The majority of this land would have a peak flood depth of less than 500mm, hence the estimated loss of flood storage would most likely be in the order of 2-5% of the total 100 year flood storage currently available along Bellbird Creek. The effect on downstream flood levels is not expected to be significant.

Limestone Creek

Figure 13 & **Figure 14** plot the predicted 20, 100, 500 year ARI and PMF peak water surface profiles in the Limestone Creek channel. As previously discussed, the right hand bank of Limestone Creek acts as a natural levee, as any flood level exceeding the top of bank would discharge over the bank and into the proposed residential development areas located between Limestone and Bellbird Creeks. In order to predict the frequency of overtopping of Limestone Creek, a comparison of flood levels in Limestone Creek and the estimated right over-bank level was undertaken (*refer plot of these levels in **Figure 13***). Additionally, a 500mm freeboard (*reduction in right over bank level*) was applied to account for variations in right overbank level, superelevation of flow around bends and other possible obstructions (*i.e. a log jam*) which may locally increase flood levels within the channel. It is noted that a Manning's roughness value of 0.07 was adopted for the channel, this would be considered conservative given the current scarcity of vegetation in the channel. However, the creek rehabilitation strategy discussed in **Section 6,** would involve revegetation of the channel resulting in a likely channel roughness of 0.07 (*as modelled*).

As shown in **Figure 13** and **Figures 19, 21** and **22,** the predicted 500 year ARI flood level is at least 500mm below the adopted right bank level (*500 mm freeboard applied to estimated level*) between chainages 2250 and 4000. The right overbank is generally lower (*relative to flood levels*) between Chainages 0 and 2250, hence modelling predicts that some overtopping of Limestone Creek could occur downstream of Chainage 2250 during flood events at about the 100 year ARI flood level. The predicted PMF flood level, shown in **Figure 13**, approximately ranges between 0.5 to 1 meter above the adopted top of bank between chainages 2250 and 4000 meters. This implies that a significant volume of water (*preliminary estimated to be between 100 m^3/s to 250 m^3/s*) would overtop the Limestone Creek system between Chainages 2250 and 4000 meters and flow through the proposed development area (*note that this is a conservative estimate, as the flood model over-estimates the PMF flood levels, as a result of "vertical" walls at the edges of the floodplain, and does not currently allow for "weir" flow over the right hand bank of Limestone Creek spilling to wards Bellbird Creek*). Also (*as noted in **Figure 13***) the level of overtopping during floods as rare as the 1 in 500 year event would not be catastrophic, with only minor overtopping occurring, and provided there is sufficient provision for overland flow between Limestone and Bellbird Creek through the development (*e.g along roadways, or through designated overland flow paths*), we can see no reason to preclude development in these areas.

The following recommendations should be considered to reduce the flood hazard of Limestone Creek overtopping:

- ❒ **Controlled Flow Diversion Between Bellbird and Limestone Creeks through the Riparian Corridor**:- Modelling indicates that in flood events up to a 500 year ARI event, overtopping of Limestone Creek would not occur upstream of Chainage 2250 meters. However, as previously discussed, flood events in excess of the 100 year ARI event may locally overtop the Limestone Creek channel between Chainages 0m and 2250m. The riparian habitat corridor connecting Bellbird with Limestone Creeks between chainages 2000m and 2250m (refer **Figure 2)** has been identified as possible high-flow relief area, which if implemented would reduce the probability of Limestone Creek overtopping into residential areas between chainages 0m and 2250m. It is recommended that engineering solutions be further investigated such as the provision of a depressed swale area between Limestone and Bellbird Creeks in this area, as well as the construction of a hydraulic control on the downstream side of the diversion area (*i.e a bridge*). Implementation of such works could potentially manage the diversion of floodwaters during infrequent flood events from Limestone Creek into Bellbird Creek in a controlled manner. It is noted that, if designed appropriately, an engineered diversion through this area would not increase flows in Bellbird Creek as any flow in excess of the Limestone Creek channel capacity under existing conditions would overtop the channel at some point between chainages 0 and 2000 meters regardless of whether the controlled diversion was provided. Hence, introducing a controlled diversion would direct the overtopping through a designated area, reducing the probability of uncontrolled overtopping into the proposed residential area adjacent to the right bank between chainages 0 and 2000 meters;

- **Managing Overtopping in the upper reaches during extreme flood up to the PMF:-**As previously discussed, an extreme flood (i.e. greater than a 100 year event) event could result flood water over- topping the Limestone Creek channel system. While the occurrence of such an event would be extremely rare, there is a possibility that some residents would be exposed to flood hazards during such an event. Hence, it is recommended that the effect of such an event be accounted for in the subdivision design and planning controls. Factors that could be considered are:
    - Provision of a flood warning system for Limestone and Bellbird Creeks;
    - Provision of adequate overland flow paths to minimise inundation depths during extreme events;
    - Provision of adequate emergency evacuation routes; and
    - Provision of adequate flood refuge for all affected dwellings.

Due to the complexity of this flooding scenario, it is recommended that a more detailed investigation using a 2-D hydrodynamic model be conducted at later stages of the development. This would allow for an accurate real time simulation of the overtopping of Limestone Creek and the resulting flooding in adjacent proposed residential areas during extreme events. Model results would be used to aid the design of the subdivision layout, and define evacuation routes (*as required*) and flood refuge areas.

Tributaries

Figure 15 and **Figure 17** plot the predicted 20, 100, 500 year ARI and PMF peak water surface profiles in Limestone Creek Tributary One and Bellbird Creek Tributary Two respectively. As shown in **Figure 24** the proposed development along Bellbird Creek Tributary 2, requires approximately 2.2 ha of land to be filled within the 100 year flood extent. This was accounted for in the discussion regarding filling within Bellbird Creek above.

Modelling of all other minor tributaries throughout the study area indicated that the extreme flood extents would be contained within the designated floodplain / riparian corridors. Hence, there would be no significant flooding constraints imposed on the proposed development.

4.6 FLOOD HAZARD CATEGORISATION

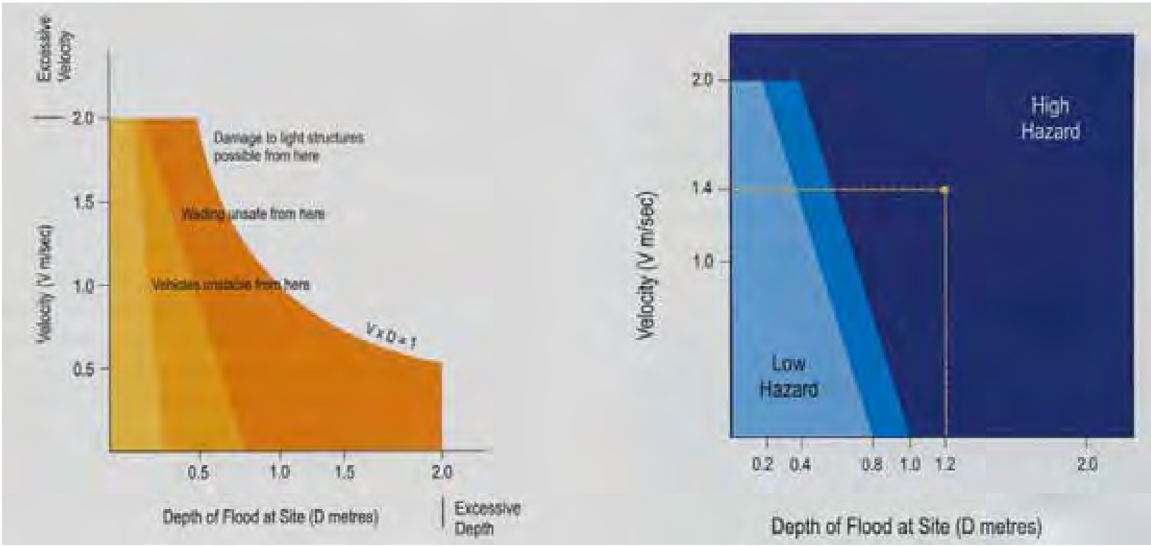
The personal danger and physical property damage caused by a flood varies both in time and place across the floodplain. Accordingly, the variability of flood patterns across the floodplain over the full range of floods needs to be understood.

Representation of the variability of flood hazard across the floodplain provides floodplain managers with a tool to assess the existing flood risk and to determine the suitability of land use and future development. The hazard associated with a flood is represented by the static and dynamic energy of the flow, which is in essence, the depth and velocity of the floodwaters. Therefore, the flood hazard at a particular location within the floodplain, is a function of the velocity and depth of the floodwaters at that location.

The *Floodplain Development Manual* (9) characterises hazards associated with flooding into a combination of three hydraulic categories and two hazard categories. Hazard categories are broken down into high and low hazard for each hydraulic category as follows:

- Low Hazard – Flood Fringe
- Low Hazard – Flood Storage
- Low Hazard – Floodway
- High Hazard – Flood Fringe
- High Hazard – Flood Storage
- High Hazard - Floodway

As a result, the manual effectively divides hazard into two categories, namely, high and low. An interpretation of the hazard at a particular site can be established from the following graphs, which have been taken directly from the manual.



The first of these shows approximate relationships between the depth and velocity of floodwaters and resulting hazard. This relationship has been used to define the provisional low and high hazard categories represented in the second of these plots.

4.6.1 Adopted Hazard Categorisation

As shown above, flood hazard is a measure of the degree of difficulty that pedestrians, cars and other vehicles will have in egressing flooded areas, and the likely damage to property and infrastructure. At low hazard, passenger cars and pedestrians (*adults*) are able to move out of a flooded area. At high hazard, wading becomes unsafe, cars are immobilised and damage to light timber-framed houses would occur.

Flood hazard is categorised according to a combination of the flow velocity and the depth of floodwater. The categories are defined by lower and upper bound values for the product of flow velocity and floodwater depth. The *Floodplain Development Manual* (9) criteria specified above were used to define the flood hazard categories with which computer modelling results for Bellbird, Limestone and Lavender Creeks (*including spatial and temporal distributions of flow, velocity and water level*) were interpreted to produce flood hazard mapping.

4.6.2 Provisional Flood Hazard Assessment

Results from the computer modelling completed for this study were combined with this hazard category criteria to generate provisional flood hazard mapping for the design 100 year recurrence floods. Mapping showing the flood extent and the variability in flood hazard for these events is presented in **Figure 23**. The limit of the low hazard area effectively defines the flood extent for each of these floods.

The hazard represented in this mapping is provisional only. This is because it is based only on an interpretation of the flood hydraulics and does not reflect the effects of other factors that influence hazard. For example, the impacts associated with areas of very high hazard may be reduced if an effective local flood plan is developed, implemented and maintained under the guidance of the State Emergency Services (*SES*).

4.7 FLOOD WARNING, EVACUATION AND EMERGENCY RESPONSE MEASURES

As shown in **Figure 18**, a PMF flood event would inundate a significant portion of the site. While a flood of the magnitude of PMF is an unlikely occurrence, it is important to minimise risk to the public and provide suitable evacuation paths or flood refuge during such an event. With reference to **Figure 18,** proposed development areas adjacent to Bellbird Creek would become inundated by at least 1 meter of water during a PMF (*conservative estimate*). However, during events such as a 500 year event, the level of overtopping and inundation is well within acceptable levels for the proposed development areas. This is an important consideration, in that we believe that development should not be precluded on the grounds of the level of overtopping during a PMF event.

However, modelling of a PMF event indicates that the peak flood levels could occur over the site within 90 minutes of the beginning of rainfall. Given the short timing and considering that many access roads would be quickly cut off, it is considered unlikely that the development area could be entirely evacuated. Hence, the emergency response plan would apply the following risk management criteria to all proposed development land within the PMF flood extent:

- **Flood Warning:-** It is recommended that (*regardless of whether evacuation could take place*) flood warning sensors be provided on both Bellbird and Limestone Creeks. The sensors would alert the SES and other government authorities when flood levels reached levels required for notification of residents, and for SES to examine the possibility of evacuation during longer duration events. This would provide the maximum time for evacuation, reducing the flood hazard across the study area. Flood sensors would also have a positive benefit for local areas, as the flood warning could also be applied for the Cessnock township and other adjoining areas (*e.g. Bellbird*).

- **Hazard Management:-** The degree of hazard to be managed is a function of the type of development and residential mobility (*Section L6.9- Floodplain Development Manual* [9]*, , 2005*). The *Floodplain Development Manual* [9] designates schools as requiring special evacuation needs due to the increased problems imposed with evacuation. It is noted that the previous school location is immediately to the south of the confluence of Bellbird and Limestone Creeks. Due to the increased difficulties in evacuating schools, this site has been identified as being unsuitable for a school site. Therefore, it is recommended that the school site be relocate to the western side of Limestone Creek as shown in **Figure 39.** This would result in an reduction in the overall flood hazard over the site.

- **Evacuation /Escape Routes:-** continually rising escape routes to areas above the PMF flood level would allow residents a low hazard escape route. Proposed escape routes would be above the predicted 100 year ARI level. They would typically be along roadways which are not intended to be overland flow paths for significant stormwater conveyance and be continually rising to a location which is flood free during a PMF event. Considering the short catchment response time during an extreme event, it is recommended that the proposed nominated escape routes be limited to 400 – 600 meters in length.

- **Flood Refuge:-** In some cases residents may not be able to evacuate so it is recommended that flood refuge or 'vertical evacuation' be provided in all dwellings within the PMF flood extent. This can be achieved by ensuring that criteria for low flood hazard is not exceeded for all dwellings within the PMF extent. Typically this would require flood levels to not exceed 500 to 700 mm above any habitable floor level for the PMF event. Alternatively, building in areas where this criteria might be exceeded could allow for vertical evacuation into an upper floor (*i.e. recommend that all dwellings in areas inundated to levels greater than say 500-700mm above flood levels be two storey dwellings*).

Implementation of the above flood risk management options would significantly reduce the flood hazard for all residents. A preliminary flood emergency response plan showing proposed areas required to meet the flood refuge requirements and possible evacuation routes (*note: if feasible to evacuate, given the timing of the particular event*) and is presented in **Figure 40**. As the subdivision layout has not been finalised it is recommended that a detailed flood emergency response plan be provided as part of the development application stage of the planning. This plan would be prepared with close liaison with the *State Emergency Service* (*SES*), *Department of Environment and Climate Change* (*DECC)* and Council.

5 WATER QUALITY ASSESSMENT

This section details the proposed water quality control guidelines for the site. A water quality model is used to estimate the pollutant removal efficiency of a number water quality control options, allowing for a quantitative assessment of the effectiveness of the stormwater management plan (*SWMP*) in meeting the water quality performance objectives outlined in **Section 1.2.**

5.1 WATER QUALITY MANAGEMENT OPTIONS

5.1.1 Discussion

Water quality control is an important aspect of the SWMP. The preservation of acceptable water quality is essential in order to maintain the environmental, recreational and aesthetical qualities of the on-site creeks and other downstream water bodies. The following extract from **Table 13.2** in the *Australian Runoff Quality (ARQ)* (16) summarises the key adverse impacts of urbanisation on waterways:

1) Increased rate and volume of runoff;
2) Increased frequency of high velocity flows;
3) Increased rates of erosion, sedimentation and channelisation;
4) Reduction in the loss of riparian zones;
5) Reduction in the loss of in-stream habitat;
6) Decreased water quality;
7) Containment of sediments;
8) Introduction of barriers to the dispersal of biota and the loss of continuity between up-stream and downstream communities; and
9) Reduced diversity of indigenous flora and fauna and the introduction of pests and weeds.

The intention of this water quality assessment is to provide water quality guidelines to be adopted for the proposed urban development. These guidelines would address the nine potential impacts of urbanisation on local waterways listed above. The guidelines include:

- Establishment of water quality control strategies;
- Establishment of water quality treatment targets;
- Indicative sizing of water quality and quantity control devices; and
- Establishment of riparian corridors and stream rehabilitation strategies.

Recommended design guidelines provide a framework which can be integrated into the development control strategy. **Section 6** discusses the stream rehabilitation and riparian corridor aspects, while the water quality control strategies are discussed in the remainder of **Section 5**.

5.1.2 Water Quality Control Options

Water quality control strategies for the study area have been developed in accordance with the principles recommended in *ARQ* (16), from which both the qualitative and quantitative aspects of the manual have been considered. The following treatment opportunities have been identified as possible water quality controls.

- **Preventative Measures –** apply at the subdivision scale and would incorporate:-
  - Minimising areas of impervious surfaces - by reduced road widths and increased landscaping around dwellings; and
  - Public education – information can be provided to residents to inform them of stormwater management issues and provide recommendations on how they can minimise their impact.
- **Source Controls -** apply at the lot level and would incorporate: -
  - Rainwater Tanks - to capture roof water runoff and for reuse of water within the development. The rainwater tanks would also provide some limited stormwater treatment and runoff attenuation;
  - Permeable Pavers - can be implemented into driveways or parking bays to provide subsurface retention storage and stormwater treatment.
  - Minimising areas of impervious surfaces - by reduced road widths and increased landscaping around dwellings; and
- **Conveyance Controls -** applied at the street level and would incorporate: -
  - Bio-filtration areas – can be integrated into the urban landscape in a longitudinal swale or a basin area (*commonly referred to as rain gardens*). The bio-filtration areas would consist of vegetated areas with enhanced filtration media which would typically be 500-600mm deep. Filtered stormwater would be collected in an underlying subsurface drainage system and directed into roadside drainage. The bio-retention areas could be designed to provide 2 year detention storage, negating the need for downstream basins in some catchment areas;
- **End of Line Controls -** apply at the end of the stormwater system and would incorporate:-
  - Gross Pollutant Traps (*GPTs*) – can be easily integrated into piped drainage system providing removal of gross pollutants (*i.e litter*) and coarse sediments.
  - Constructed Wetlands / Detention Basins – can be implemented to treat stormwater prior to discharge into receiving waters. Wetlands would be designed to incorporate, sediment fore bays, deep water zones and ephemeral (*'wet and dry'*) macrophyte (*reed*) beds to achieve maximum pollutant removal and maintenance efficiencies. Extended and active detention can also be provided above the permanent pool to meet water quantity management objectives.

Additionally, the proposed development offers significant opportunities for rainwater harvesting primarily through the implementation of rainwater tanks where captured rainwater would be re-used at a lot scale to supplement the garden watering, toilet flushing and washing machine demands. Furthermore, extraction from on-site storages could be used for irrigating open space and sporting fields in the area.

However, it is noted that the development master plan is currently assessing the viability of a waste water recycling scheme, which would provide a third pipe source of recycled water to residents within the development. If such a system was implemented it would negate the demand for stormwater harvesting, hence making such systems unnecessary or uneconomical.

5.1.3 Water Quantity Targets

The hydrologic analysis detailed in **Section 3** established that flooding in Limestone, Bellbird and Lavender Creeks is primarily governed by runoff from areas upstream of the study area. Hydrologic modelling using *RAFTS* software demonstrated that implementation of stormwater detention would provide no benefit from a flood mitigation point of view. Hence, water quantity control targets are governed from the point of view of maintaining the natural flow regime during frequent rainfall events. This is discussed further below.

The increased hydraulic efficiencies typical of urban catchments can result in "*peak discharges corresponding to a 5 year ARI event in a rural catchment occurring on average twice a year following urban development of a catchment*" (*ARQ, IEAust, 2006*) [(16)]. The increased frequency of moderate flooding disturbs the natural flow cycle which is crucial to maintaining aquatic biodiversity. Furthermore, increasing the flood frequency would result in an increase in the occurrence of stream forming flows (*typically defined as a 2 year ARI event*) resulting in increased erosion rates of downstream waterways. Hence, the following water quantity management targets have been adopted to minimise the disturbance to the local water cycle:

- Provide 20 mm of extended detention per unit of impervious area in urban subcatchments. This can be integrated into water quality control devices such as wetlands, rainwater tanks, permeable pavers and bio-retention swales. Extended detention should be designed so that it empties with in 48 hours of the cessation of rainfall;

- Provide stormwater detention to reduce peak developed flows to existing condition levels for all storms up to the 2 year return period. Modelling has indicated that this would require a volume approximately equivalent to 10mm per unit of impervious areas in urban subcatchments when applied in conjunction with the 20mm of extended retention; and

- Additional retention would be provided in the permanent water zone of constructed wetlands if rainfall occurs after a prolonged dry period, this has not been accounted for in the hydrologic modelling.

The adopted water quantity controls would require approximately 30mm of storage per unit of development area, this equates to approximately 200 m^3 of storage per hectare of urban development.

5.1.4 Water Quality Treatment Targets

An accurate estimate of the existing water quality of the site is difficult to determine without long and detailed water quality monitoring records. Furthermore, it is possible that parts of the site in its current condition *(i.e. grazing operations),* could have higher pollutant export loads than a stabilised urban catchment. As such, a more reasonable approach is to adopt methods as outlined in *ARQ* [16] and current Best Management Practice (*BMP*), which recommend the following water quality treatment objectives:-

- Suspended Solids (TSS) 80% retention of the developed average annual load
- Total Phosphorous (TP) 45% retention of the developed average annual load
- Total Nitrogen (TN) 45% retention of the developed average annual load

A water quality model (*MUSIC*) was used to estimate the expected pollutant loads from the proposed development. The following sections describe the modelling methodologies and report the estimated performance of the proposed water quality controls.

Section 5.3 presents three stormwater management options which would achieve both the water quality and quantity objectives and are suitable for implementation across the site.

5.2 WATER QUALITY MODEL

MUSIC is a continual-run conceptual water quality assessment model developed by the Cooperative Research Centre for Catchment Hydrology (*CRCCH*). MUSIC can be used to estimate the long-term annual average stormwater volume generated by a catchment as well as the expected pollutant loads. MUSIC is able to conceptually simulate the performance of a group of stormwater treatment measures (*treatment train*) to assess whether a proposed water quality strategy is able to meet specified water quality objectives.

To undertake the water quality assessment, a MUSIC model was established for the Bellbird site. The model was used to estimate the pollutant load generated from the development and estimate the indicative size of water quality controls required to meet the water quality targets defined in **Section 5.1.4**.

5.2.1 Model Parameters

In order to establish a MUSIC model, rainfall and evaporation records in the vicinity of Bellbird were sought.

Rainfall

In order to develop a model that could comprehensively assess the performance of the proposed SWMP, the use of 6 minute pluviograph data was considered necessary. The nearest Bureau of Meteorology (*BoM*) weather station is located at Millfield (*BoM Station 061174)* [13] which is approximately 7 km from the study area the site. The rainfall records obtained from BoM Station 061174 extend between 1959 to 1980 and were reviewed to determine that the average annual rainfall depth is approximately 818mm. Observed rainfall between 1969 and 1973 was used for all MUSIC water quality simulations. This period was selected as it represents 5 consecutive years of approximate average rainfall.

Evaporation

Monthly areal potential evapotranspiration (*PET*) rates for the sites were estimated from PET data provided by the Climate Atlas of Australia (BoM) (6). The monthly average PET adopted for the MUSIC model are shown in **Table 5-1**.

Table 5-1 – Monthly Areal Potential Evapotranspiration

Month	Areal Potential Evapotranspiration (mm)
January	180
February	145
March	135
April	90
May	65
June	55
July	50
August	70
September	95
October	135
November	145
December	163

Catchment Parameters

MUSIC simulates the generation, mobilisation and removal of the following pollutants:-

- Total Suspended Solids (*TSS*);
- Total Phosphorus (*TP*); and
- Total Nitrogen (*TN*).

The pollutant loadings for each catchment are proportional to the land use and the impervious area fraction. The following three general land uses were adopted for the MUSIC modelling:-

- Urban Roads;
- Urban Roofs; and
- Other Urban pervious areas.

The event mean concentrations (*EMC*) for each of these land uses were derived from '*Urban Stormwater Quality: A Statistical Overview*' (*Duncan, February 1999*) (14) and '*Australian Runoff*

Quality' (*Engineers Australia, 2006*) [16]. Adopted EMCs for each land use are detailed in **Appendix G**.

5.2.2 Model Results

An assessment was undertaken in MUSIC to determine the pollutant removal efficiencies for various water quality control options. The results are discussed in **Section 5.3.1.**

It is noted that MUSIC simplifies a complex environment where many physical and bio-chemical processes can potentially influence the water quality. As MUSIC algorithms are based on observed average water quality performances (*which are highly variable*) it does not consistently accurately represent a modelled scenario. All efforts have been made in this study to realistically represent the water quality scenario, however the MUSIC results should be only be considered as estimates of average conditions only. As with any statistical representation, results could potential be above or below average conditions. Hence, some degree of variability should be expected in the performance of the proposed SWMP.

5.3 RECOMMENDED STORMWATER MANAGEMENT STRATEGIES

Three generic water quality control treatment options have been identified as being suitable for implementation across the site. These are summarised as follow:

- **Type 1 – End of Pipe treatment**. This option would incorporate gross pollutant traps and constructed wetlands at the downstream discharge point of the proposed urban catchments. The constructed wetland would incorporate extended detention storage above the permanent wetland to allow for both water quality and water quantity control. **Figure 28** presents the typical wetland design.

- **Type 2 - Water Sensitive Urban Design Approach**. As only 2 year detention storage is required, the need for large downstream basins is not required. Hence, on-lot and conveyance controls may be implemented to achieve both the water quality and quantity control objectives. This would negate the need for downstream controls. It is recommended that 20mm of extended detention storage could be integrated into the urban landscape through the use of rainwater tanks, permeable pavers and bio-retention areas. Remaining detention storage would be provided above the bio-retention areas. **Figure 28** presents the typical bio-retention swale design.

- **Type 3 - Rural Residential Lots**. Areas designated for rural residential development would incorporate a lower impervious area percentage and a high proportion of open space than the higher density urban areas. Hence, all stormwater management objectives would be achieved using onsite stormwater controls such as rainwater tanks, permeable pavers and grassed soak-aways. Bio-retention areas would provide treatment for road and driveway areas.

Each of the above stormwater management types can be selected based on the constraint imposed by topography and available land for end of pipe constraints. It is noted that the steeper topography in the upper catchment may impose limitations on the effectiveness of the use of constructed wetlands. In these area, Type 2 (*WSUD*) may be the most appropriate treatment measure.

5.3.1 Preliminary sizing of Stormwater Management Controls

Preliminary sizes of stormwater management controls required for each treatment type were estimated using MUSIC modelling to assess the required controls to meet the water quality treatment targets stipulated in **Section 5.1.3**, and storage volume estimates to meet the water quantity requirements outlined in **Section 5.1.4**. Calculations for each option were based on a typical 1 hectare urban (*or rural residential for Type 3*) catchment. As MUSIC is a load based model, the required size of water quality control devices is proportional to the upstream urban catchment. Therefore, the required water quality treatment sizes for any catchment can be calculated by multiplying the catchment area (*in hectares*) by the required treatment sizes for a one hectare catchment. This method also can be applied to water quantity calculations as the storage requirements are directly proportional to the impervious area (*i.e. 20 mm of extended detention storage per unit of impervious area*) within a catchment.

Table 5-2 presents preliminary sizing of stormwater management control devices based on *MUSIC* model results and *RAFTS* based storage volume calculations. Detailed *MUSIC* results are attached in **Appendix G**.

Table 5-2 – Preliminary sizing of stormwater management control options

Stormwater Management Control Strategy	Required size to meet water quality treatment targets (*all sizes for 1 ha catchment*)	Required size to meet water quantity targets (*all sizes for 1 ha catchment*)	Governing size of treatment controls (*all sizes for 1 ha catchment*)
Type 1 **End of Pipe treatment**	1. 200 m^2 of wetland area 2. Standard GPT	1. 130 m^3 of extended detention storage 2. 65 m^3 of active detention storage (2yr ARI)	1. 200m^2 of wetland with 130 m^3 of extended detention storage and 65 m^3 of detention storage[1] 2. Standard GPT
Type 2 **WSUD**	1. 80 m^2 of bio-retention filter area treatment (assuming filter media is 600mm deep)[2] Note: Treatment and flow attenuation provided by the permeable pavers was accounted for in the *MUSIC* model	1. 120 m^3 of extended detention storage provided in permeable pavers 2. 10 m^3 of extended detention provided in bio-retention filter media[2] 3. 65 m^3 of active detention storage (2yr ARI) provided above filter media[2]	1. 120 m^3 of extended detention provided in permeable pavers with an estimated 360 m^2 surface area 2. 80m^2 of bio-filtration media with 65 m^3 of active detention storage provided above filter media
Type 3 **Rural Residential**	1. All roof areas drain to a grassed soak away 2. 25 m^2 of bio-retention filter area treatment for road areas [2]	1. 30 m^3 of extended detention storage above bio-retention filter media[2]	1. All roof areas drain to a grassed soak away 2. 25 m^2 of bio-retention filter with 30 m^3 extended detention

1 refer to **Figure 28** for concept design drawing
2 refer to **Figure 28** for bio-filtration area concept design drawing

It is noted that all the calculations in **Table 5-2** do not account for the benefits of rainwater tanks. This was intentionally in this way because at the time of writing it was unclear whether a third-pipe recycled water system would be implemented for the development. If rainwater tanks are adopted, the benefits can be incorporated into stormwater management control strategies at the development application stage of planning.

6 RIVERS AND FORESHORES IMPROVEMENT ACT – PART 3A PERMIT REQUIREMENTS

6.1 RIVERS AND FORESHORES IMPROVEMENT ACT

The Rivers and Foreshores Improvement Act 1948 (*R&FI Act*)[20] applies to obtaining approval for works within the 'protected land' of a waterbody or waterways.

From 27 April 2007 a new *Department of Water and Energy* was created and the *Department of Natural Resources* (*DNR*) and *Department of Energy*, Utilities and Sustainability ceased to exist. The *Department of Environment and Conservation* changed its name to the Department of Environment and Climate Change (*DECC*) and undertook some functions previously managed by *DNR*.

It is our understanding that under the most recent changes the *R&FI Act* [20] will be administered by the *Department of Water and Energy* (*DWE*), rather than the *DECC*.

Part 3A of the *R&FI Act* [20] requires a permit to be obtained prior to works being undertaken within the 'protected land' including works within the waterway or waterbody or within adjacent land 40m from the top of their banks. Each permit has conditions that are specific to the type of activity undertaken to ensure there are no adverse impacts on the riparian environment and to manage an environmentally acceptable solution.

There are three significant ephemeral creeks that traverse the site. These are Lavender, Bellbird and Limestone Creeks. Each is fed by an array of smaller tributaries and ephemeral watercourses and overland swales. A description of the significant streams is presented in the following sections.

The purpose of a *Part 3A* permit under the *R&FI Act* [20] is to control activities that have the potential to cause adverse impacts such as:

- Increased erosion or siltation of watercourses or lakes;
- Bed lowering and bank collapse;
- Diverting the course of a watercourse;
- Obstructing or detrimentally affecting stream flow; and
- Ecological deterioration, leading to long term watercourse stability problems.

6.2 EXISTING WATERCOURSES

There are a number of existing watercourses on the subject site, these include:

(i) Lavender Creek (*north western corner of the site*);

(ii) Limestone Creek (*falling from the western boundary of the site through a number of tributaries to Limestone Creek itself, which then joins Bellbird Creek at the north-eastern corner of the site*); and

(iii) Bellbird Creek, (*running from south to north along the eastern boundary of the site*).

In addition to the above named creeks, there are a number of minor category 1 and 2 streams on the site, which feed into these, particularly Limestone and Bellbird Creeks. The Creeks and associated tributaries are shown in **Figure 29**.

A description of the significant watercourses traversing the site is outlined below in **Sections 6.2.1** to **6.2.3**.

6.2.1 Lavender Creek

Lavender Creek traverses the north western corner of the site over a length of approximately 700m. In this area, the creekline is dominated by a chain of farm dams, such that the natural ephemeral creekline has all but disappeared. There are a number of remnant "hollows" and billabongs, however, for the most part, the area is dominated by existing dams, and grassed swales between the dam storages, where floodwaters would spread out, without the existence of a formalised low flow channel in many section of the creek. The remnant sections are localised to within existing farm dams and are not directly connected together by open channel.

Typical remnant "billabong" along Lavender Creek

Typical remnant channel section along Lavender Creek approx 30m long

Typical remnant channel with grasses and some riparian shrubs and trees remaining

Typical existing farm dam along Lavender Creek

6.2.2 Limestone Creek and Tributaries

Limestone Creek falls from the western boundary of the site through a number of tributaries to Limestone Creek itself, which then joins Bellbird Creek at the north-eastern corner of the site.

Limestone Creek and its tributaries through the subject site can be characterised into two distinct zones as follows:

i) **Upper Tributaries -** the upper (*south and western portion of the site*), where the four main tributaries of Limestone Creek congregate. In this area, the southern two tributaries are characterised by heavily vegetated channel and overbank regions that appear relatively stable, despite the relatively steep gradient of these channels (*relative to say Bellbird Creek, and its other Tributaries*). Tributary 1 is almost in a pristine condition, with very little clearing of existing remnant vegetation through the site, and relatively little impact from the construction of farm dams etc. In this instance, the tributary forms a natural gully which is relatively incised, but does not meander significantly. Tributary 2 is similar to Tributary 1, although there has been significantly more clearing, and there is a large farm dam in the upper reaches of this channel. Tributary 3 is essentially denuded of riparian vegetation, and is significantly affected by farm dams, and appears to have no significant habitat values. Tributary 4 has some minor remnant vegetation, however is less affected by significant farm dams.

ii) **Limestone Creek** – Limestone Creek itself is characterised by a relatively steep gradient (*compared to the neighbouring Bellbird Creek*), significant meander bends, and significant evidence of head cuts (bed lowering), and bank erosion. The stream morphology includes significant pool and riffle sequences characterised by very tight meander bends. The erosion evident at the outside of many of the meander bends results in significantly high (*up to 5m*) banks resulting from toe scour and increased shear stresses around the outside of the bend. The majority of the length of Limestone Creek from the confluence with Bellbird Creek up to the area where the four major tributaries join the channel has been significantly cleared of vegetation. There are some sparse stands of remnant vegetation along the length of the creek however these are typically isolated to between one to five trees at the top of bank of meander bends. Limestone creek also has a small tributary in the lower reaches (Tributary 5), which has been essentially denuded of remnant vegetation and is significantly affected by a large farm dam at the headwaters.

Limestone Creek channel showing significant bed lowering and bank erosion

Limestone Creek channel showing sweeping meander bends with erosion caused by cattle

Limestone Creek channel showing significant height of banks at meander bends

Limestone Creek Tributary 1 - showing dense existing remnant riparian vegetation and stable bed and banks

6.2.3 Bellbird Creek and Tributaries

Bellbird Creek runs from south to north along the eastern boundary of the site. There are two tributaries of Bellbird Creek running through the site, these are described as follows:

i. **Tributary 1 -** rises within the urban development area to the south of the site, and discharges through a constructed channel running along the western boundary of the playing fields and tennis courts at Carmichael Park. Downstream of this constructed channel the remnant creekline is further to the east running north –south parallel to Prince Street. It is obvious that the Carmichael Park facilities were filled over the top of the pre-existing channel, and that the constructed channel was created as a diversion of overland flows from the upstream catchment around the western side of the playing fields. The existing constructed channel tails out to nothing some 200m downstream of the playing fields, and does not appear to be directly connected to the remnants of the stream further to the north-east. The remnant stream is in reasonable condition, although mostly denuded of native vegetation for much of its length. In addition, there is one farm dam located approximately 50m downstream of the playing fields, and another just downstream of the Abbotsford Road alignment. The remnant stream reforms towards the confluence with Bellbird Creek, and is in reasonable condition with some significant cover of vegetation for the 100m or so near the confluence with Bellbird Creek.

ii. **Tributary 2 -** rises within the site itself (*Tennant Street forms the southern boundary of the subject site, is also the southern catchment boundary for this tributary*). This tributary is barely a waterway, and seems to be more an overland flowpath, with little or no remnant vegetation, and a number of shallow depressions forming farm dams along the alignment. Towards the middle third of this overland flowpath, the gradient drops right down such that under existing conditions, the runoff would most probably pond significantly and either soak away or pond and then continue to runoff towards Bellbird Creek.

Bellbird Creek channel – showing some remnant floodplain species

Bellbird Creek channel – showing some remnant floodplain species

Bellbird Creek Floodplain – showing some remnant floodplain species near the confluence with Tributary 1

Bellbird Creek Tributary 1– showing no remnant species, and constructed, degraded channel

Bellbird Creek Tributary 2– showing no remnant species, only grassed overland flowpath through paddocks

6.3 CATEGORISATION OF WATERWAYS, AND SUGGESTED RIPARIAN BUFFER WIDTHS

Based on our assessment of the waterways on the subject site, we note the following categorisation of the streams, based on the guidelines outlines in the Department of Natural Resources letter dated 10 November 2006.

Appendix H outlines the methodology used to determine the stream categorisation, in accordance with the Department's guidelines (*Department of Land and Water Conservation "Farm Dams Assessment Guide"*) (23).

Based on our assessment of the streams, we would suggest the following categories and minimum setback distances relating to creeks and its tributaries as they run through the site:

Table 6-1 – Derivation of Suggested Riparian Corridor Setback Distances

Stream	Estimated Stream Category[23]	Typical Department of Water & Energy Required Riparian Setback Distances[23]	Typical Condition (*Patterson Britton site inspections*)	Suggested riparian setback distances	Recommended Rehabilitation Measures
Lavender Creek					
Lavender Creek	2	20 m from top of bank	Degraded, some remnant section, large farm dams	20 m from top of bank	Removal of farm dam(s), and revegetation of channel banks and overbank areas to corridor width
Limestone Creek					
Tributary 1	2-3	20-30 m from top of bank	Pristine, full riparian vegetation, no farm dams	20-30 m from top of bank	None required, some removal of noxious weeds, if necessary
Tributary 1B	1	10 m from top of bank	Significant riparian vegetation	10 m from top of bank	Minimal revegetation required of channel banks and overbank areas to corridor widths
Tributary 2	1	10 m from top of bank	Some significant riparian vegetation, large farm dam	10 m from top of bank	Removal of farm dam, and revegetation of channel banks and overbank areas to corridor widths
Tributary 3	1	10 m from top of bank	Degraded, no significant remnant sections, small farm dams	None	Suggested that this stream is not worthy of retention as a watercourse, it is significantly degraded, and has no significant habitat benefit. It is suggested that this become an overland flow corridor within the urban development, with appropriate trunk drainage provided within the design.
Tributary 4	2	20 m from top of bank	minor riparian vegetation	20 m from top of bank	Removal of farm dam(s), and revegetation of channel banks and overbank areas to corridor width
Tributary 5	1	10 m from top of bank	Degraded, no significant remnant sections, large farm dams	None to 10m towards the confluence with Limestone Creek	Suggested that this stream is not worthy of retention as a watercourse, it is significantly degraded, and has no significant habitat benefit, and has a large farm dam. It is suggested that this become an overland flow corridor within the urban development, with appropriate trunk drainage provided within the design.
Limestone Creek – Main Channel	3	30m from top of bank	Degraded, head-cuts, significant bank erosion, little remnant vegetation, some farm dams	20m provided significant rehabilitation and bed / bank protection works incorporated	Removal of farm dam(s), and revegetation of channel banks and overbank areas to corridor width. Channel rehabilitation works to include bed control structures (*rock riffles*), and bank protection works at the outside of meander bends. Refer details in **Section 6.4** below.
Bellbird Creek					
Tributary 1	1 - 2	10m – 20m from top of bank	Some significant	10m – 20m from top of	Removal of farm dam, and revegetation of channel banks and

			riparian vegetation, large farm dam	bank	overbank areas to corridor widths
Tributary 2	1	10 m from top of bank	Degraded, no significant remnant sections, small farm dams	None	Suggested that this stream is not worthy of retention as a watercourse, it is significantly degraded, and has no significant habitat benefit. It is suggested that this become an overland flow corridor within the urban development, with appropriate trunk drainage provided within the design. As shown on the attached **Figure 40**, as overland flows exceed the capacity of the local pipe drainage and overland flow capacity of road systems, trunk drainage channels may be required to safely convey excess runoff into the surrounding creek systems. Note these may be either vegetated with natives, or landscaped to look more urban, while retaining some habitat and water quality benefits.
Bellbird Creek – Main Channel	3	30m from top of bank	Slightly degraded, some localised bank erosion, significant remnant vegetation, some small farm dams.	30m	Removal of farm dam, and revegetation of channel banks and overbank areas to corridor widths. No other engineering works proposed to rehabilitate the channel, besides localise battering back of overly steepened section in areas denuded of remnant species.

While we note from the above that there are some proposed reductions in the typical set back distances required by the Department of Water and Energy, however, as outlined below in **Table 6-2** and **Figure 37**, the suggested overall riparian areas (*including areas to be retained as nature conservation areas*) by far exceed the requirements of the Department. Therefore, it is our belief that the Department should accept the riparian buffer distances outlined above in **Table 6-1**.

Table 6-2 – Comparison between typical Department of Water & Energy Riparian Corridor Areas, and Estimated Adjusted Minimum Riparian Zones

Stream	Estimated Stream Category (ref. X)	Typical Department of Water & Energy Required Riparian Setback Distances (ref Y)	Estimated Area of Riparian Zone (m^2)	Suggested riparian setback distances (*refer Table 6.1 above*)	Estimated Adjusted Area of Riparian Zone (m2)	Suggested overall riparian areas (*including areas to be retained as nature conservation areas*) (m^2)
Lavender Creek						
Lavender Creek	2	20 m from top of bank	32,300	20 m from top of bank	32,300	56,000
Limestone Creek						
Tributary 1	2-3	20-30 m from top of bank	82,300	20-30 m from top of bank	82,300	196,900
Tributary 1B	1	10m from top of bank	19,800	10m from top of bank	19,800	92,500
Tributary 2	1	10 m from top of bank	45,700	10 m from top of bank	45,700	118,500
Tributary 3	1	10 m from top of bank	1,200	None	0	0
Tributary 4	2	20 m from top of bank	33,400	20 m from top of bank	33,400	53,600
Tributary 5	1	10 m from top of bank	6,800	None to 10m towards the confluence with Limestone Creek	5,700	74,400
Limestone Creek – Main Channel	3	30m from top of bank	417,700	20m provided significant rehabilitation	370,600	414,100
Bellbird Creek						
Tributary 1	1	10m – 20m from top of bank	88,500	10m – 20m from top of bank	88,500	262,800
Tributary 2	1	10 m from top of bank	35,900	None	-	-
Bellbird Creek – Main Channel	3	30m from top of bank	140,700	30m	140,700	210,540
Total Development Area	**-**	**-**	**904,300**	**-**	**819,000**	**1,479,340**
Additional vegetation conservation areas not associated with riparian corridors						97,500

6.4 RECOMMENDED CREEK REHABILITATION WORKS FOR LIMESTONE CREEK

As discussed previously the channel of Limestone Creek exhibits evidence of significant bed and bank erosion due to loss of riparian vegetation, cattle grazing and flood scour caused by high stream velocities in this relatively steep and incised channel, particularly at the outside of meander bends.

Peak flood velocities for a range of storm frequencies at select locations along Limestone Creek are shown below in **Table 6-3**.

Table 6-3 – Mean Channel Velocities

River Reach	River Station	5 year ARI	100 year ARI
4	97.48	1.63	1.56
4	466.3	1.35	1.59
4	622.77	1.66	2.01
4	793.4	0.92	1.17
4	997.99	1.43	1.69
4	1190.83	0.87	1.12
4	1378.46	1.12	1.42
4	1395.18	1.06	1.32
4	1448.28	1.89	2.41
4	1584.49	1.06	1.19
4	1751.07	1.32	0.84
4	1925.64	1.67	3.5
4	2128.51	1.35	1.37
4	2208.09	1.66	2.13
4	2351.97	1.21	1.35
4	2609.13	0.89	1.08
4	2821.02	2.02	2.22
4	3060	1.33	1.76
4	3076.33	1.25	1.61
4	3280.72	0.7	0.8
4	3747.08	1.8	2.6
4	3953.34	1.55	1.87
4	4117.06	1.02	1.33
5	34.83	2.67	2.18
5	139.68	0.73	0.84
5	287.07	1.86	2.58
5	314.64	0.95	1.12
5	584	1.43	1.53

Review of the above and with reference to **Figure 13** it can be seen that the longitudinal profile of the Limestone Creek main channel has two distinct reaches of slightly differing channel gradient. Lower Limestone Creek between the confluence of Bellbird Creek and Limestone Creek Tributary 1 has an average longitudinal gradient of approximately 0.4%, and is characterised by sub-critical flow, with typical in-bank (i.e. 5 year ARI) channel velocities of between 1.0 to 1.9 m/s, and "flood" (i.e. 100 year ARI) velocities of between 1.2 and 2.6 m/s. The upper reach of Limestone

Creek between the Tributary 1 confluence and the western site boundary has a slightly steeper profile at around 0.8%, with in-bank (i.e. 5 year ARI) channel velocities of around 0.9 to 2.5 m/s, and "flood" (i.e. 100 year ARI) velocities of between 1.1 and 2.5 m/s. There is also one location, where the channel reaches supercritical flow, near the confluence with Tributary 1.

Accordingly, the following recommendations are made to alleviate further degradation of the stream, and to alleviate the potential for erosion and undermining of adjacent proposed infrastructure:

i) Introduction of rock riffles at select location along the Limestone Creek channel. The rock riffles would be designed to withstand the typical in-stream channel velocities, and would be located at existing channel inflexion points. The rock riffles would be designed using natural locally sources rock, and would be designed to minimise any potential limitation to habitat movement along the creekline. Typical details of proposed rock riffles are shown in **Figure 35** and **Figure 36**. Typical locations of proposed rock riffles are shown in **Figure 30**.

ii) Battering back to a maximum of 1V to 3H of over-steepened banks to provide a more stable matter that is not prone to sudden failures, and that can accommodate the planned riparian planting;

iii) Battering back to a maximum of 1V to 3H at the outside of over-steepened meander bends to provide a more stable matter that is not prone to sudden failures, and the provision of a rock revetment including bed and bank protection around the outside of meander bends. The rock revetment would also be planted out with riparian groundcover species. A typical section of this revetment and riparian planting treatment is shown in **Figure 35**. **Figure 30** indicates typical meander bends where this type of treatment could be applied.

iv) Full riparian planting to the widths specified in **Table 6-1** above. Full details of the riparian species to be planted would be provided by the landscape architect at the detailed design stage for a *Part 3A* permit application under the *R&FI Act* [(20)].

The above measures would re-establish the degraded pool and riffle sequence, ensuring that further bed lowering and head-cuts are isolated and arrested. In addition, the battering back of banks, bank protection works and revegetation proposed at the meander bends would protect the over-steepened banks from further erosion.

In order to ensure that the rehabilitated channels remain stable, and does not threaten adjacent proposed development, a riparian setback of 20m from the top of the battered back top of banks is recommended. Bank and overbank areas would be protected by the soil binding properties of the vegetation, and fallen trees would provide additional material for the creation of pool and riffle sequences, such that the overall channel form and stability will be consolidated.

We note that a more detailed assessment of the creek rehabilitation measures would be undertaken at the detailed design stage.

6.5 HARVESTABLE RIGHTS ASSESSMENT

In a letter dated 10 November 2006, the *Department of Natural Resources* (*DNR*) discussed the requirement for a Harvestable Rights Assessment to be conducted.

The *Water Management Act* (*2000*) [(22)], prepared and administered by the then DNR gives landholders the right to capture and use for any purpose 10% of the average regional yearly rainfall runoff for their property [(22)]. This is known as the Harvestable Right and for management purposes is implemented as a corresponding total dam capacity for the property. It is intended to satisfy essential farm needs such as for stock watering, house and gardens and may be used for any purpose, including irrigation.

Table 6-4 summarises calculations undertaken to determine the Harvestable Rights for the North Bellbird site[(22)].

Table 6-4 – Harvestable Rights Calculation for North Bellbird site

Site Area (ha)	497
Harvestable Rights Multiplier (ML/ha)	0.82
Harvestable Rights (ML)	**407.5**

Several farm dams are present on the North Bellbird site and an estimation of their volume was undertaken to determine whether the current number of dams exceed the Harvestable Rights allowance. In order to estimate the existing farm dam storage volumes, an estimate of the dam top surface areas was undertaken by measuring the areas from the survey plans of the site. Based on a visual inspection, an approximation of the ponded average depth was made at 1.0m. As can be seen in **Table 6-5** below, the total existing farm dam storage volume on the subject site is approximately 40.8 ML. As discussed in **Section 6,** the majority of farm dams within the site would be either filled or breached as part of the proposed development works.

An approximation of the potential volume of constructed wetlands proposed on the site was undertaken, based on water quality calculations outlined in **Section 5**. As discussed in **Section 5,** Type 2 and Type 3 stormwater management configurations would not incorporate any permanent storage (*i.e. in a constructed wetland*). It is noted that the *Water Management Act* (2000)– Schedule 2 (*Exempt Classes of Dam*), under Item No. 2 "Dams solely for flood detention and mitigation, provided no water is reticulated or pumped from such dams" [(22)]. Hence, as all detention and extended detention controls would be designed to empty with 48 hours of the cessation of rainfall these stormwater controls are exempt from harvestable rights calculations. Therefore, the total proposed permanent storage would be governed by the extent of constructed wetland required to meet the Type 1 stormwater management control criteria. With reference to **Appendix J,** the proposed total wetland surface area over the site is estimated to be 37,000 m^2. This would equate to an approximate volume of 37 ML (*based on an average permanent pond depth of 1m*). Additionally, a maximum permanent storage estimate was made based on Type 1 treatment being applied globally across the site. In this case the estimated wetland area would be 65,000m^2, resulting in a permanent storage volume of 65 ML for the site. These permanent storage estimates are presented in **Table 6-5.**

Table 6-5 – Comparison of Existing Farm Dam and Proposed Retention Storage Volumes

Existing Farm Dams (ML)	40.8
Proposed Constructed Wetland Volume (ML)	37
Estimated Maximum Wetland Volume (ML)	65
Allowable Harvestable Rights for the site (from Table 6-4)	**407.5**

As shown in **Table 6-5,** both the proposed and estimated maximum constructed wetland volumes are less than the estimated harvestable rights volumes. Hence, the proposed development would comply with the harvestable rights requirements of the *Water Management Act* (2000) [(22)] and *Cessnock City Council DCP No. 55*[(23)].

Full details of Harvestable Rights Calculations can be found in **Appendix I**.

7 SUGGESTED DEVELOPMENT CONTROLS – RECOMMENDED STORMWATER MANAGEMENT, FLOOD PLANNING CONTROLS AND CREEK REHABILITATION MEASURES

This section establishes recommended development controls with regard to stormwater, floodplain management and creekline riparian corridor / rehabilitation for the proposed North Bellbird development area. The recommended controls are the result of the engineering investigations detailed in this report. Furthermore, a conceptual flooding and stormwater management plan has been established for the site. The development control plan collates results from all investigations undertaken for this study and identifies development constraints as well as recommended strategies for managing the stormwater, flooding and creek rehabilitation issues identified for the site.

7.1 RECOMMENDED STORMWATER MANAGEMENT DEVELOPMENT CONTROLS

This section outlines recommended development controls established from the engineering investigations conducted in this report. Many of the controls are specific to this study and are linked to model results (*i.e. flood levels*).

7.1.1 Stormwater Management (Water Quality and Quantity)

Stormwater management controls are required to mitigate the adverse impacts of urban development on both the water quality and hydrological cycle in the receiving waters. **Section 5.1** discusses the water quality and quantity treatment objectives recommended to be adopted for the site. These are summarised as follows:

- **Water Quality**: - Water quality treatment measures must be provided to achieve the following pollutant removal efficiencies (*relative to the developed state*):
  - 80% reduction in annual Total Suspended solids load;
  - 45% reduction in annual Total Nitrogen load; and
  - 45% reduction in annual Total Phosphorous load.

  Pollutant removal efficiencies of various treatment configurations should be assessed in *MUSIC* using the model parameters presented in this report.

- **Water Quantity:-** Water quantity controls must meet the following criteria:
  - Extended detention storage volume equivalent to 20mm per unit of impervious area in the urban catchment. The extended detention storage would be required to be designed so that any proposed storage empties in approximately 48 hours; and

- o Detention storage to achieve parity with predicted existing state peak flow rates during a 2 year ARI, 120 min storm (*typical critical duration for the development areas*).

As discussed in **Section 5**, three stormwater management control Types were identified as being suitable for implementation into the proposed development, as follows:

- ❒ **Type 1 – End of Pipe treatment**. This option would incorporate gross pollutant traps and constructed wetlands at the downstream discharge points of the proposed urban catchments. The constructed wetlands would incorporate extended detention storage above the permanent water level to allow for both water quality and water quantity control. **Figure 28** presents a typical wetland / detention system design.

- ❒ **Type 2 - Water Sensitive Urban Design Approach**. As only 2 year ARI detention storage is required, the need for large downstream basins is not necessary. Hence, on-lot and conveyance controls may be implemented to achieve both the water quality and quantity control objectives. This would negate the need for downstream controls. It is recommended that 20mm of extended detention storage could be integrated into the urban landscape through the use of rainwater tanks, permeable pavers and bio-retention areas. Remaining detention storage would be provided above the bio-retention areas.

- ❒ **Type 3 - Rural Residential Lots**. Areas designated for rural residential development would incorporate a lower impervious area percentage and a higher proportion of open space than the higher density urban areas. Hence, all stormwater management objectives would be achieved using onsite stormwater controls such as rainwater tanks, permeable pavers and grassed soak-aways. Bio-retention areas or permeable pavements would provide treatment for road and driveway areas.

Table 7-1 presents preliminary sizing of stormwater management control devices based on *MUSIC* model results and *RAFTS* based storage volume calculations. Detailed *MUSIC* results are attached in **Appendix G**.

Table 7-1 – Preliminary sizing of stormwater management control options

Stormwater Management Control Strategy	Governing size of treatment controls (*all sizes for 1 ha catchment*)
Type 1 **End of Pipe treatment**	1. $200m^2$ of wetland with 130 m^3 of "extended detention" storage and 65 m^3 of detention storage[1] 2. Standard GPT
Type 2 **WSUD**	1. 120 m^3 of "extended detention" provided in permeable pavers with an estimated 360 m^2 surface area 2. $80m^2$ of bio-filtration media with 65 m^3 of active detention storage provided above filter media[2]
Type 3 **Rural Residential**	1. All roof areas drain to a grassed soak away 2. Road areas to drain to bio-retention areas - 25 m^2 of bio-retention filter with 30 m^3 of extended detention

1 refer to **Figure 28** for concept design drawing
2 refer to **Figure 28** for bio-filtration area concept design drawing

Table 7-1 defines the suggested stormwater management control configurations for each treatment Type. It is noted that all sizing of stormwater controls are based on the required treatment for 1 ha of typical urban development, hence, establishing a treatment control size to catchment area ratio. These ratios can be applied to larger or smaller catchments by adjusting the treatment size to reflect the size of the catchment (*i.e a 2ha urban catchment would require treatments to be twice the size as a 1 ha catchment*). It is noted that the calculations used to establish the stormwater control sizes presented in **Table 7-1** assumes that the treatment controls are evenly distributed across each urban catchment so that each area of catchment achieves approximately the same level of treatment.

It is noted that at the development application stage, refinements to the stormwater control configurations may be required. In order to ensure that the stormwater objectives are maintained, any amendments to the stormwater treatment Types would be required to meet the requirements presented in **Section 5.1.**

7.1.2 Stormwater Conveyance Controls

Stormwater conveyance systems are to be designed in accordance with the requirements stipulated in *Australian Rainfall and Runoff* (*AR&R, 1987*) [(8)] as well as the Cessnock City Council's requirements for drainage line design (*DCP 2006*) [(23)]. As shown in **Figure 40**, some engineered trunk drainage overland flow paths will be required to supplement standard urban drainage systems. These may be landscaped with either riparian type treatments, or more urban landscaping, as applicable, provided the requirements of *AR&R (1987)* [(8)] as well as Council are met.

7.2 RECOMMENDED FLOOD PLANNING CONTROLS

A flood assessment was undertaken to define the flood behaviour over the site and the resulting effect of development on flood behaviour for downstream and adjacent properties. The hydrologic aspects of the investigation are discussed in **Section 3** while the flood hydraulics assessment is discussed in **Section 4.** Predicted flood modelling results were interpreted to define predicted flood extents, levels, categorisation of Floodways and a provisional flood hazard assessment over the site. This information was used to define the following flood planning controls recommendations for the site:

- The 100 year flood level is recommended as the Flood Planning Level. All building floor levels should be at least 500mm above the Flood Planning Level;

- There shall be no ground level modifications undertaken in areas designated as 'Floodway'. However, there are expected to be some modifications to the flood affected land required as part of the urban development, including:

  i) Modifying the natural ground surface in residential areas so that floor levels of dwellings are at least 500 mm above the predicted 100 year ARI flood level;

  ii) Construction (*or modification*) of bridges across the site; and

  iii) Construction of stormwater infrastructure such as constructed wetlands within the 100 year flood extent.

  Figure 24 indicates the extent of proposed ground level modification and location of proposed bridges and constructed wetlands. It is noted that all ground level modifications and constructed wetlands are outside of areas designated as Floodway, hence it is assumed that they would have a negligible effect on flood conveyance.

  In some locations, ground surface modifications are proposed within the 100 year ARI flood extent. This would result in a minor reduction of flood storage. However, an examination of the proposed filled areas indicated that the total area of proposed filling inside the 100 year flood extent was approximately 9.1 hectares. This is less than 10% of the estimated 96.1 hectare 100 year flood extent. As shown in **Figure 24**, all proposed fill locations are on the fringe of the 100 year extent, indicating there would be no significant loss in flood storage. Hence it can be assumed that the effect on flood levels (*adjacent or downstream of the site*) due to the suggested limited filling of flood storage and flood fringe areas would be negligible.

- Areas within the 100 year flood extent, but outside the floodway areas designated may be used for recreational uses (*i.e. cycle / walking tracks and / or sporting fields*) as long as adequate provision is made for public safety (*i.e. limitations of velocities and depths, and the provision of adequate signage and egress routes from these areas*).

- There should not be any limitation to providing some of the stormwater management controls within the 100- year ARI flood envelope, provided these controls are outside of the floodway areas, and suitable native riparian vegetation is used in the landscaping of the stormwater treatment measures (*e.g. bio-retention systems or wetlands*). Appropriate controls should be provided in the design of these facilities, such that the measures provided can withstand the expected velocities and predicted depths of inundation that may be experienced. In particularly, attention should be made to the sensitive design of outlet control structures and outlet headwalls / tail out channels, in relation to potential scour, and protection of downstream aquatic habitat.

- As all proposed bridges are required to traverse land categorised as floodway, the effect of the proposed bridge crossings on the local hydraulics has been assessed. Details of the assessment are provided in **Section 4.5.2**. Minimum waterway area requirements for each of the proposed bridges as well as the predicted impact of the 100 year flood profile are presented in **Figure 25** through to **Figure 27**.

  It is proposed to upgrade the existing Abbotsford Street Bridge, which spans Bellbird Creek just to the east of the site. Currently the bridge deck intrudes into the floodway. As there are a number of dwellings immediately upstream from the bridge, it is expected that the existing bridge configuration would be a serious constriction to flood flows, and would currently affect the flood hazard and extent of property damage during a flood event along Bellbird Creek. The upgrading of Abbotsford Street bridge provides an opportunity to improve the hydraulic efficiency of the road crossing. The concept bridge option detailed in **Figure 27** would incorporate a raised bridge deck and an expanded channel width. Modelling indicates that this would result in a 500mm reduction in upstream 100 year ARI flood levels.

- As previously discussed, for extreme events (e.g. a 500 year event), no significant flood hazard is believed to occur in the areas proposed to be developed. However, events approaching a PMF could result in significant volumes of flood water over- topping the Limestone Creek system between chainages 2250 and 4000. While the occurrence of such an event would be extremely rare, there is a possibility that some residents would be exposed to higher flood hazards during such an event. Hence, it is recommended that the effect of such an event be accounted for in the subdivision design and planning controls. Factors that should be considered are:
    - Provision of a flood warning system for Limestone and Bellbird Creeks;
    - Provision of adequate overland flow paths to minimise inundation depths during extreme events;
    - Provision of adequate emergency evacuation routes; and
    - Provision of adequate flood refuge for all affected dwellings.

  Figure 40 indicates the preliminary measures that should be provided for the development, and demonstrates that the development could be planned to accommodate the required flood emergency response plan.

  Due to the complexity of this flooding scenario, it is recommended that a more detailed investigation using a 2-D hydrodynamic model be conducted as part of the preparation of the development flood emergency response plan, to be undertaken as part of development application level studies. This would allow for a more accurate real time simulation of the overtopping of Limestone Creek and the resulting flooding in adjacent residential areas. Model results would be used to aid the refinement of the design of the subdivision layout, and more accurately define potential flood refuge areas and possible flood evacuation routes (*if appropriate*).

- Until such time as the further studies are completed, suggested flood planning controls in relation to flood emergency response for areas of the development below the PMF level are outlined below:

  - **Flood Warning:-** It is recommended that flood warning sensors be provided on both Bellbird and Limestone Creeks. The sensors would alert the SES or other government authority when flood levels reached levels required for potential warning to residents of imminent flooding, and to allow the authorities to decide whether evacuation is warranted. This would provide the maximum time for flood warning (*and possibly evacuation, should it be considered warranted*), reducing the flood hazard across the study area. Flood sensors would also have a positive benefit for local areas, as the flood warning could also be applied for the Cessnock township and other adjoining areas (*e.g. Bellbird*).

  - **Hazard Management:-** The degree of hazard to be managed is a function of the type of development and residential mobility (*Section L6.9- Floodplain Development Manual, , 2005*). The Floodplain Development Manual (*NSW Government, 2005*) designates schools as requiring special evacuation needs due to the increased problems imposed with evacuation. It is noted that the previous school location is immediately to the south of the confluence of Bellbird and Limestone Creeks. Due to the relatively increased difficulties in evacuating schools, this site has been identified as being unsuitable for a school. Therefore, it is recommended that the school site be relocate to the western side of Limestone Creek as shown in **Figure 39.** This would result in an reduction in the overall flood hazard over the site.

  - **Evacuation /Escape Routes:-** continually rising escape routes to areas above the PMF flood level would allow residents a low hazard escape route. Proposed escape routes would be above the predicted 100 year ARI level. They would typically be along roadways which are not intended to be overland flow paths for significant stormwater conveyance and be continually rising to a location which is flood free during a PMF event. Considering the possible relatively short catchment response time during an extreme event, it is recommended the proposed escape routes be limited to 400 – 600 meters in length.

  - **Flood Refuge:-** In some cases residents may not be able to evacuate so it is recommended that flood refuge or 'vertical evacuation' be provided in all dwellings within the PMF flood extent. This can be achieved by ensuring that criteria for low flood hazard is not exceeded for all dwellings within the PMF extent. Typically this would require flood levels to not exceed 500 to 700 mm above any habitable floor level for the PMF event. Alternatively, building in areas where this criteria might be exceeded could allow for vertical evacuation into an upper floor (*i.e. recommend that all dwellings in areas inundated to levels greater than say 500-700mm above flood levels be two storey dwellings*).

Implementation of the above flood risk management options would significantly reduce the flood hazard for all residents. A preliminary flood emergency response plan showing areas required to meet the flood refuge requirements and potential (*if required*) evacuation routes and is presented in **Figure 40**. As the subdivision layout has not been finalised, it is recommended that a detailed flood emergency response plan be provided as part of the development application stage of the planning. This plan would be prepared with close liaison with the *State Emergency Service* (*SES*), *Department of Environment and Climate Change* (*DECC)* and Council.

We note that the flood hazard assessment of the site should not preclude the development proceeding, just that further information will assist planners in developing the site at the development application stage.

7.3 RECOMMENDED CREEK RIPARIAN CORRIDOR AND REHABILITATION MEASURES

Figure 30 and **Table 7-2** below outlined the recommended Riparian setback distances, and proposed rehabilitation measures for the development. Further details of the proposed creek rehabilitation works for the Limestone Creek Main Channel are also included in **Section 6**.

Table 7-2 – Suggested Riparian Corridor Setback Distances and Rehabilitation Measures

Stream	**Suggested riparian setback distances**	**Recommended Rehabilitation Measures**
Lavender Creek	20 m from top of bank	Removal of farm dam(s), and revegetation of channel banks and overbank areas to corridor width
L/Stone Ck Tributary 1	20-30 m from top of bank	None required, some removal of noxious weeds, if necessary
L/Stone Ck Tributary 1B	10 m from top of bank	Minimal revegetation required of channel banks and overbank areas to corridor widths
L/Stone Ck Tributary 2	10 m from top of bank	Removal of farm dam, and revegetation of channel banks and overbank areas to corridor widths
L/Stone Ck Tributary 3	None	Suggested that this stream is not worthy of retention as a watercourse, it is significantly degraded, and has no significant habitat benefit. It is suggested that this become an overland flow corridor within the urban development, with appropriate trunk drainage provided within the design.
L/Stone Ck Tributary 4	20 m from top of bank	Removal of farm dam(s), and revegetation of channel banks and overbank areas to corridor width
L/Stone Ck Tributary 5	None to 10m towards the confluence with Limestone Creek	Suggested that this stream is not worthy of retention as a watercourse, it is significantly degraded, and has no significant habitat benefit, and has a large farm dam. It is suggested that this become an overland flow corridor within the urban development, with appropriate trunk drainage provided within the design.
Limestone Creek – Main Channel	20m provided significant rehabilitation and bed / bank protection works incorporated	Removal of farm dam(s), and revegetation of channel banks and overbank areas to corridor width. Channel rehabilitation works to include bed control structures (*rock riffles*), and bank protection works at the outside of meander bends. Refer details in **Section 6.4**.
Bellbird Ck Tributary 1	10m – 20m from top of bank	Removal of farm dam, and revegetation of channel banks and overbank areas to corridor widths
Bellbird Ck Tributary 2	None	Suggested that this stream is not worthy of retention as a watercourse, it is significantly degraded, and has no significant habitat benefit. It is suggested that this become an overland flow corridor within the urban development, with

		appropriate trunk drainage provided within the design. As shown on the attached **Figure 40**, as overland flows exceed the capacity of the local pipe drainage and overland flow capacity of road systems, trunk drainage channels may be required to safely convey excess runoff into the surrounding creek systems. Note these may be either vegetated with natives, or landscaped to look more urban, while retaining some habitat and water quality benefits.
Bellbird Creek – Main Channel	30m	Removal of farm dam, and revegetation of channel banks and overbank areas to corridor widths. No other engineering works proposed to rehabilitate the channel, besides localise battering back of overly steepened section in areas denuded of remnant species.

7.4 CONCEPTUAL STORMWATER AND FLOODING MANAGEMENT PLAN

A conceptual stormwater and flooding management plan has been established for the site. This plan collates the results from the hydrologic, flooding, water quality and creek rehabilitation investigations, establishing revised engineering constraints and recommendations for the proposed development of the North Bellbird study area. **Figure 40** presents the conceptual stormwater and flood management plan for the site. Included in this plan are details of:

- Recommended application of stormwater treatment types (*as discussed in* ***Section 5.3***). Estimated stormwater control sizes are for each catchment are defined in **Appendix J**, as well as indicative locations of stormwater controls;
- Recommended overland flow path locations;
- Potential ground surface modifications to meet the requirements for dwellings above the estimated flood planning levels for the development;
- Recommended riparian set backs to allow for lateral movement of creek systems and enhancement aquatic habitat over the site; and
- Possible flood evacuation routes.

It is noted that this document is in support of a rezoning study, hence the stormwater management plan should be considered as preliminary only. As it is likely that the development master plan will change, modifications to the stormwater treatment configurations can be made by implementing the criteria outlined in the development control plan.

7.5 CONSTRUCTION PHASE

During construction, sediment and erosion control structures would be designed and installed in accordance with the NSW Department of Housing "*Managing Urban Stormwater – Soils and Construction*" (*Blue Book*). Staging of the development will minimise impacts during construction. These controls will ensure that there are no significant adverse impacts on receiving water quality during the construction stage. A detailed soil and water management plan will be required for each stage at the development application stage.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 STUDY FINDINGS AND RECOMMENDATIONS

The key findings from this stormwater and flooding engineering constraints study are summarised in the following points:

1. The site is developable from a stormwater and flooding constraints viewpoint, provided the recommendations outlined under **Section 7 – Recommended Development Controls** are adhered to.

2. A number of further studies are recommended to refine the nature of stormwater management and flooding constraints on the site at later stages of the development (*e.g. Project application / DA Stage*). We note that these studies would be best prepared in support of DA level documentation, as they can then be based on a more refined development layout proposed at the later stages. Recommended further studies include the
   - 2D hydro-dynamic modelling of extreme flood events, particularly to define the spilling of flows from Limestone Creek to Bellbird Creek across the potential developable areas;
   - Downstream hydro-dynamic modelling to confirm that the changes to the site hydrology and floodplain storage as a result of the development do not result in perceptible increases in downstream flood levels (*note this is not expected, and should not be a reason to preclude re-zoning of the land for urban development*);
   - The preparation of a flood emergency response plan for the development;
   - Stormwater Management Plans accompanying each DA, to refine the work undertaken in this study;
   - More detailed creek rehabilitation strategy to accompany Development Applications adjacent to the relevant section of creekline, particularly Limestone Creek; and
   - More detailed flood impact assessments for actual bridge configurations / filling plans associated with each stage of the development (*where relevant*).

9 REFERENCES

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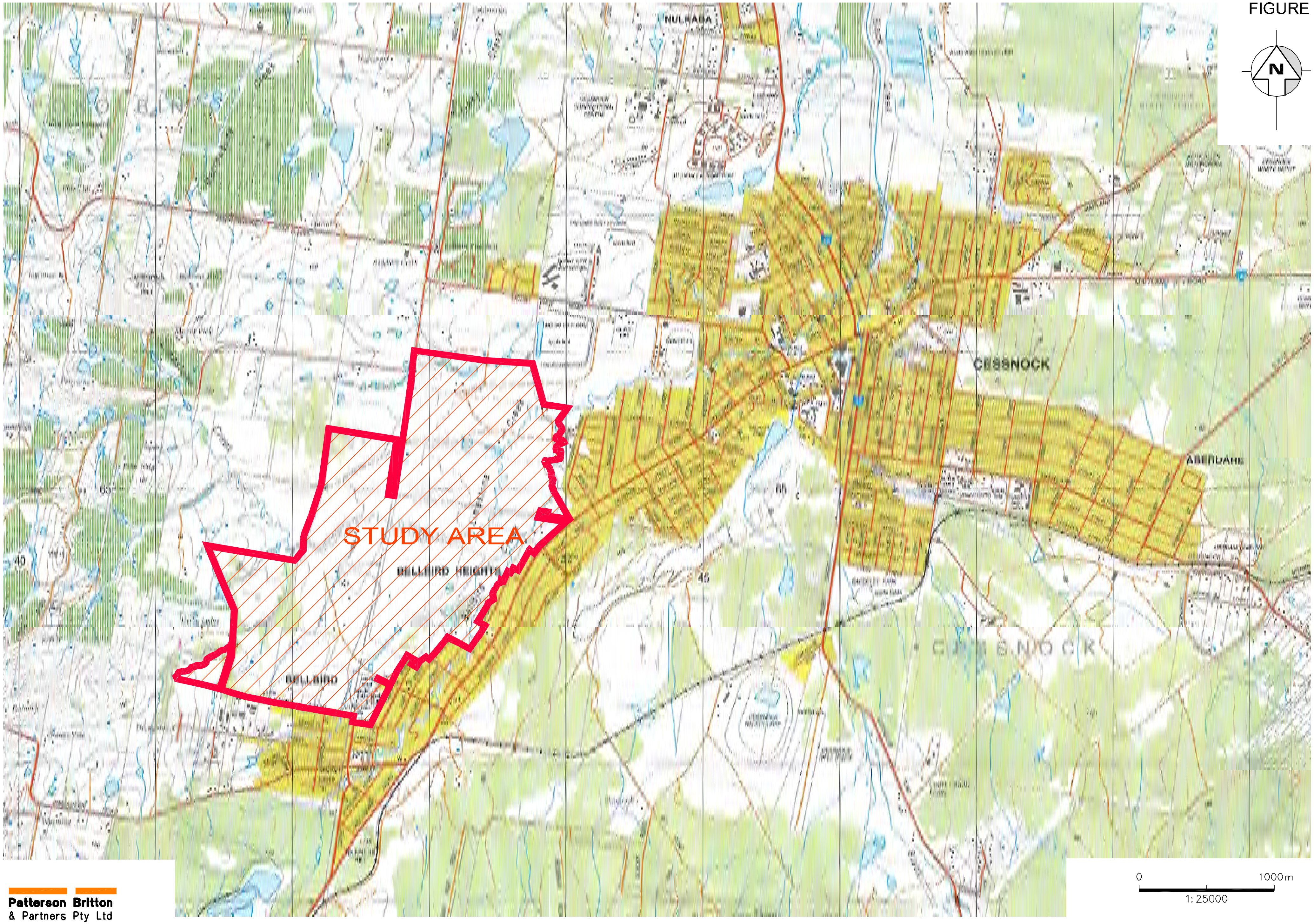
21) NSW Department of Planning, 2004, 'BASIX'

22) NSW Department of Planning, 2002, 'Water Management Act 2002

23) Cessnock City Council , 2006, 'Development Control Plan 2006, Construction of Dams'

FIGURES

FIGURE 1



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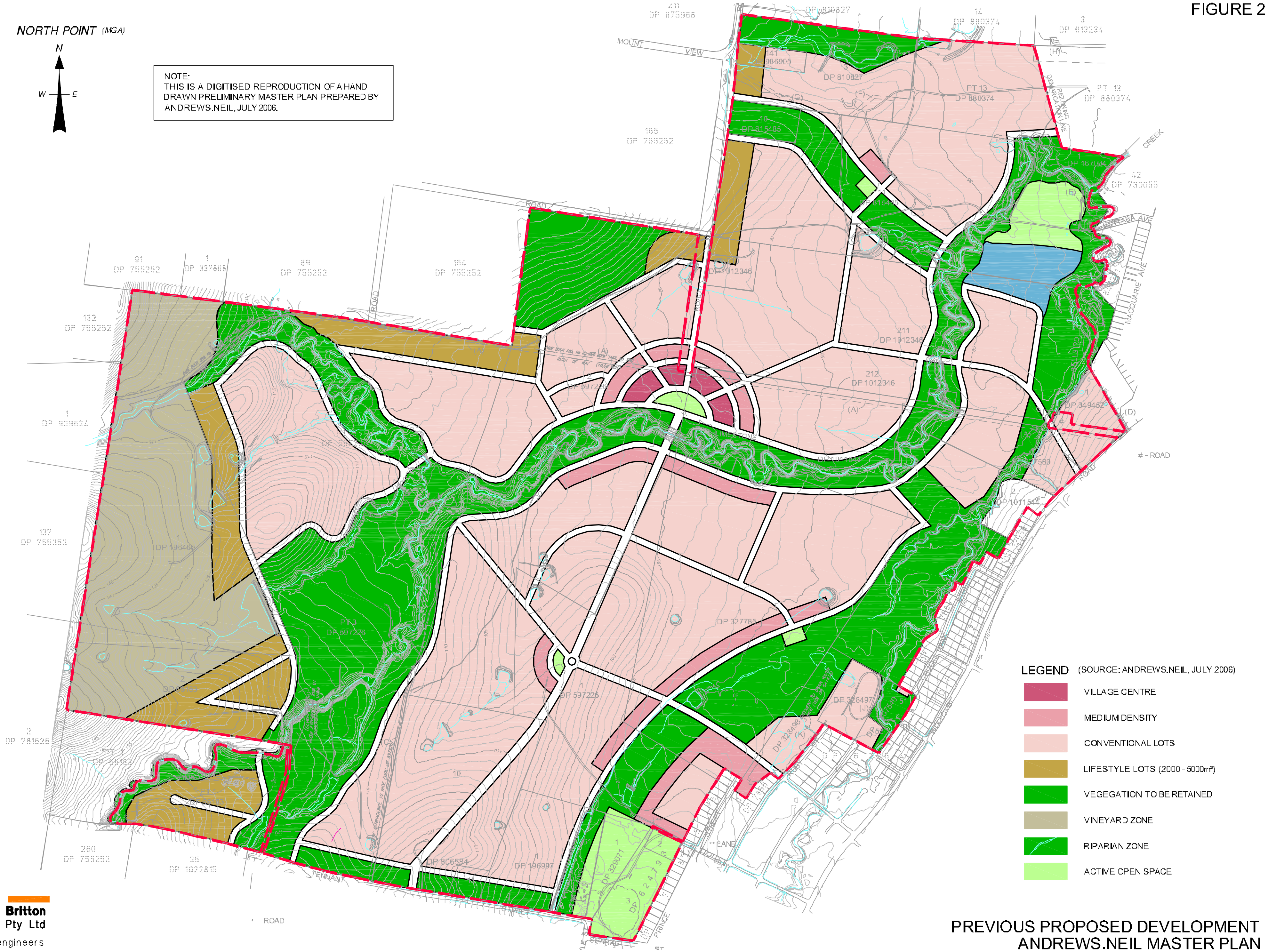
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 1 – SITE LOCALITY PLAN.dwg 09/08/2007

SITE LOCALITY PLAN

FIGURE 2



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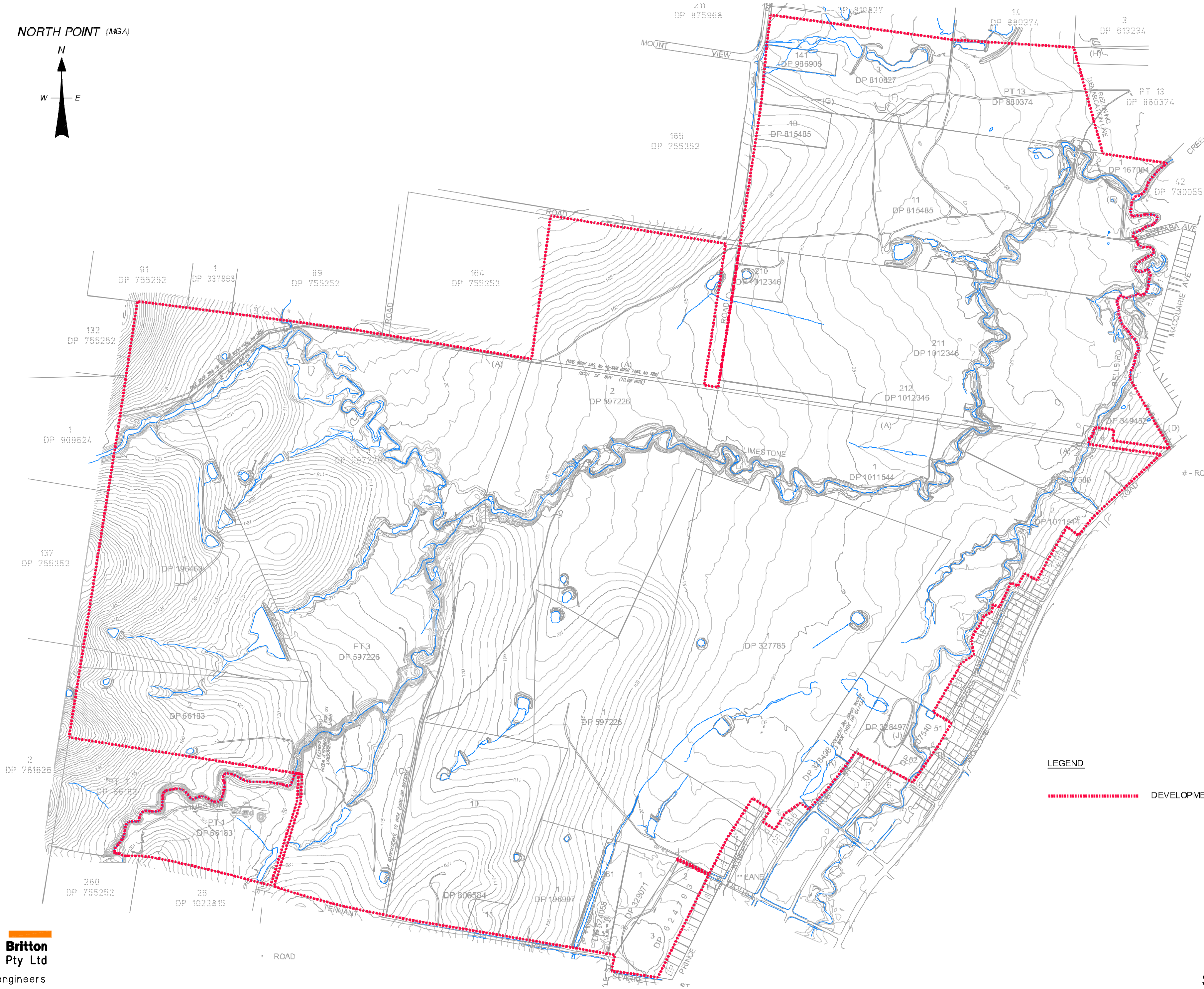
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 2 - PROP DEVELOP MASTER PLAN.DWG 09/08/2007

PREVIOUS PROPOSED DEVELOPMENT
ANDREWS.NEIL MASTER PLAN

FIGURE 3



LEGEND

DEVELOPMENT BOUNDARY

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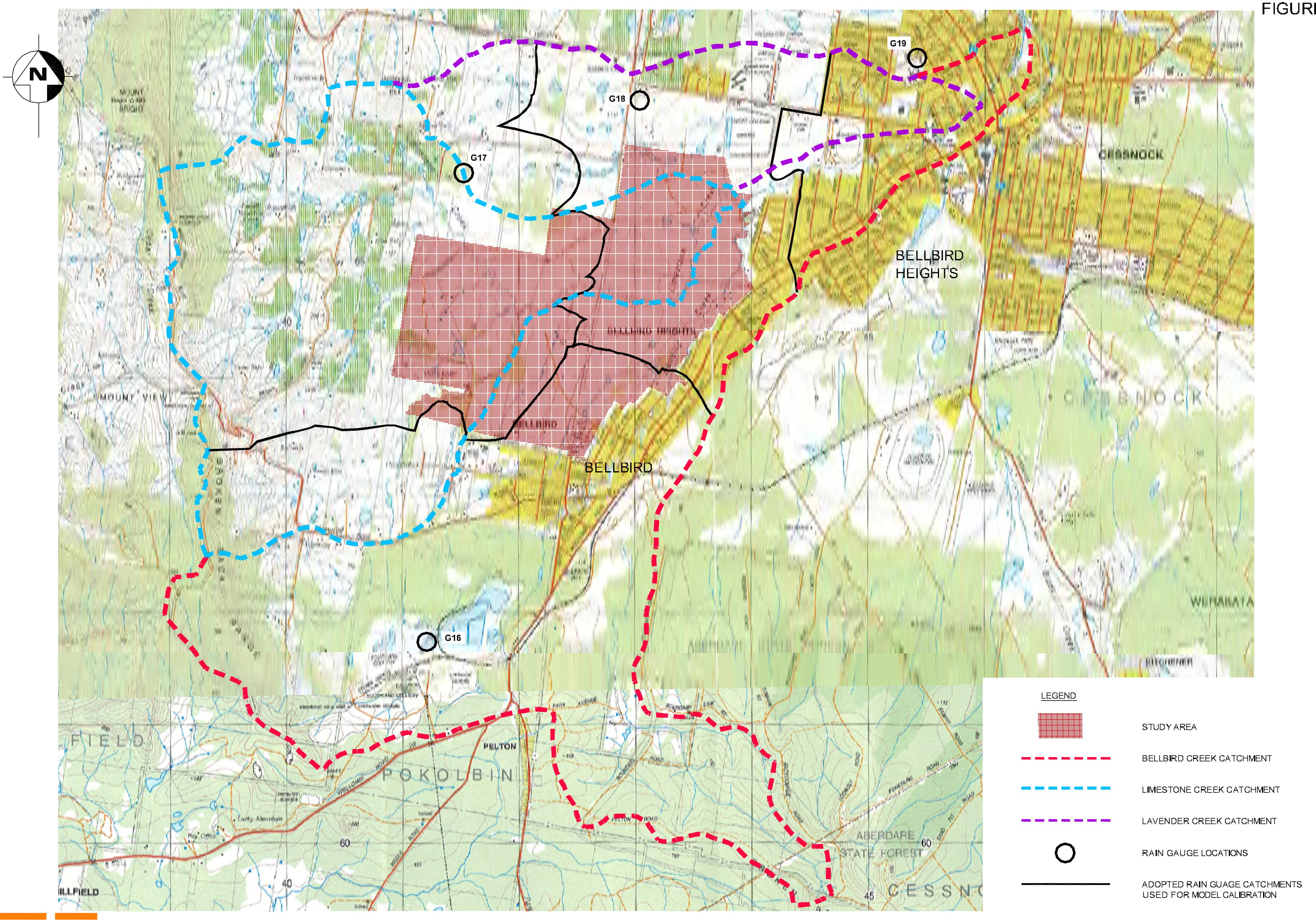
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 3 - SITE SURVEY.dwg 09/08/2007

SITE SURVEY

FIGURE 4



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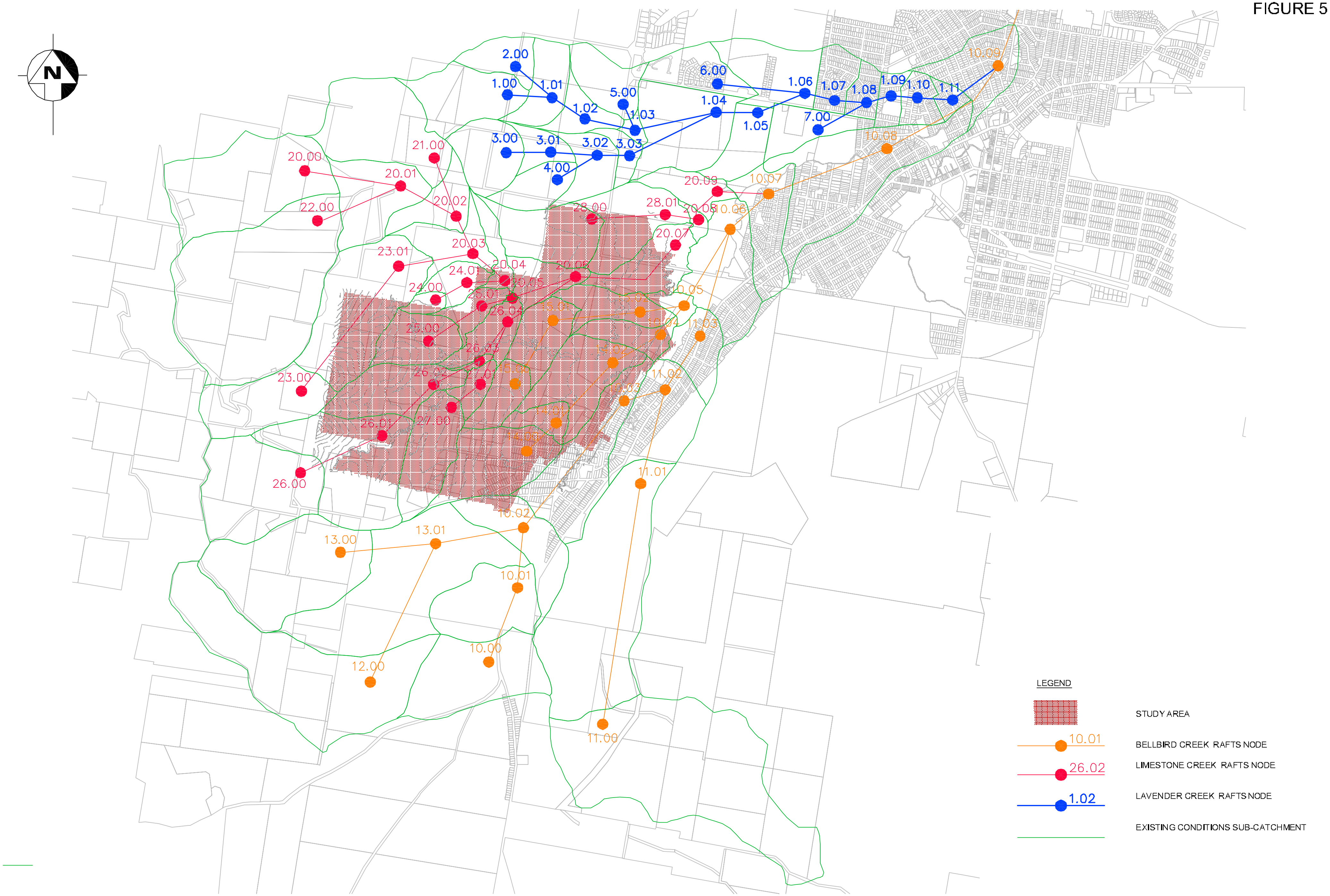
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 4 - CATCHMENT EXTENTS.dwg 09/08/2007

CATCHMENT EXTENTS

FIGURE 5



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N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 5 - EXIST SUBCATCHMENT CONFIG.dwg 09/08/2007

EXISTING STATE SUB-CATCHMENT CONFIGURATION

FIGURE 6

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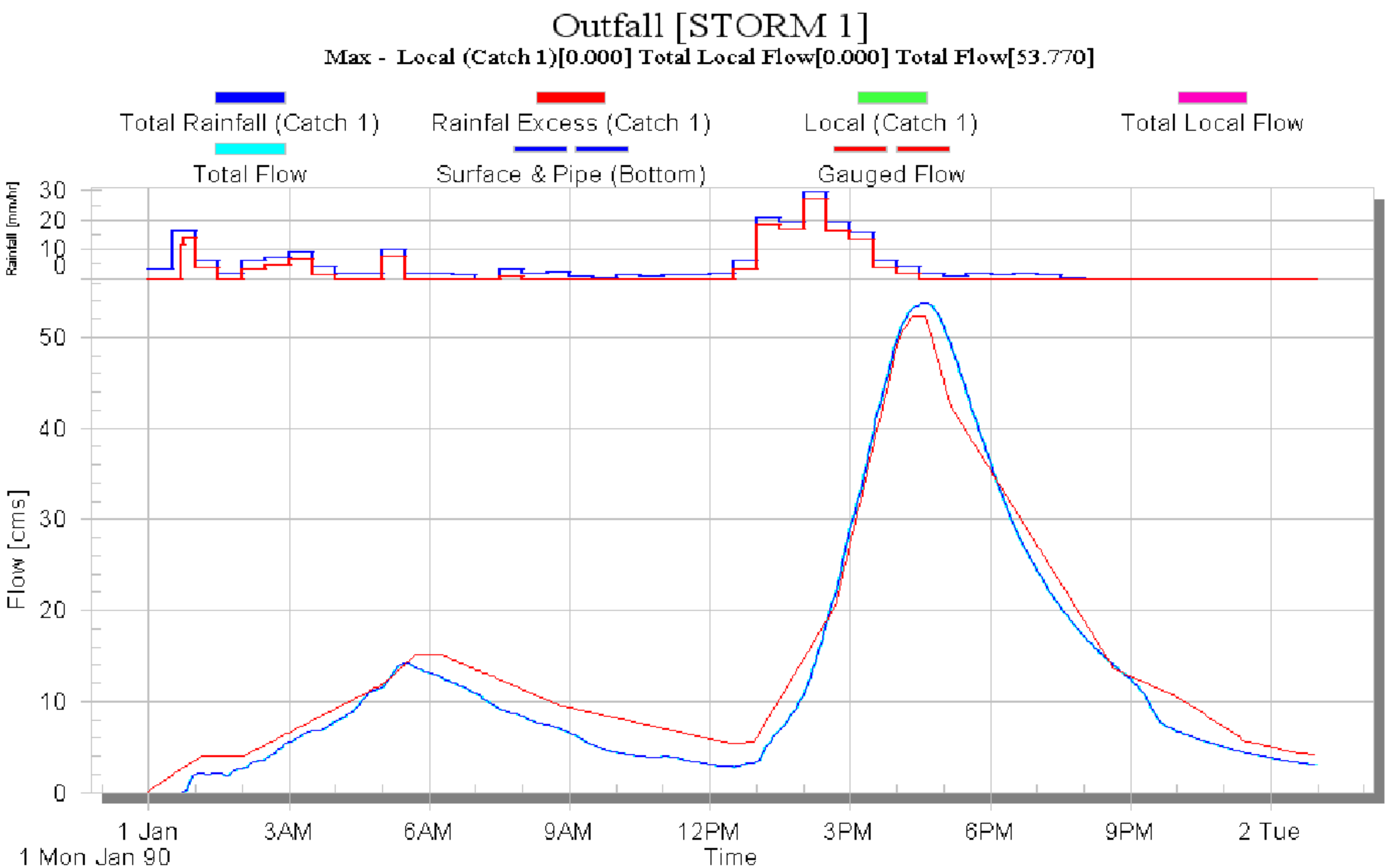
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 6 - DEVELOPED SUBCATCHMENT CONFIG.dwg 09/08/2007

DEVELOPED STATE
SUBCATCHMENT PLAN



HYDROLOGIC MODEL
FEBRUARY 1990 EVENT - CALIBRATION RESULTS
AT CONFLUENCE OF BLACK CREEK & BELLBIRD CREEK

FIGURE 7

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N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 7 - HYD MODEL CALIBRATION RESULTS.dwg 09/08/2007

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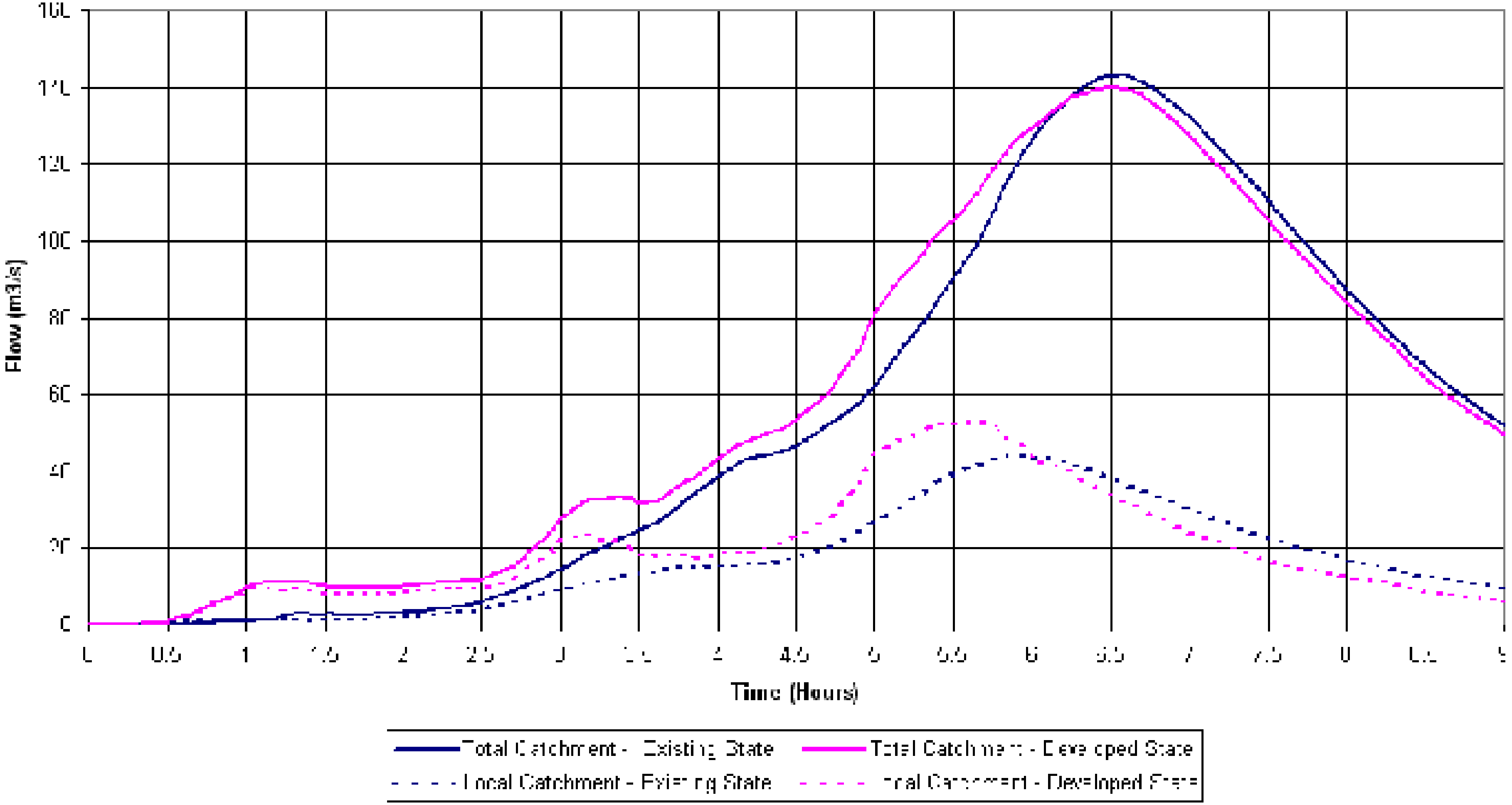
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 8 – HYD MODEL RESULTS.dwg 09/08/2007

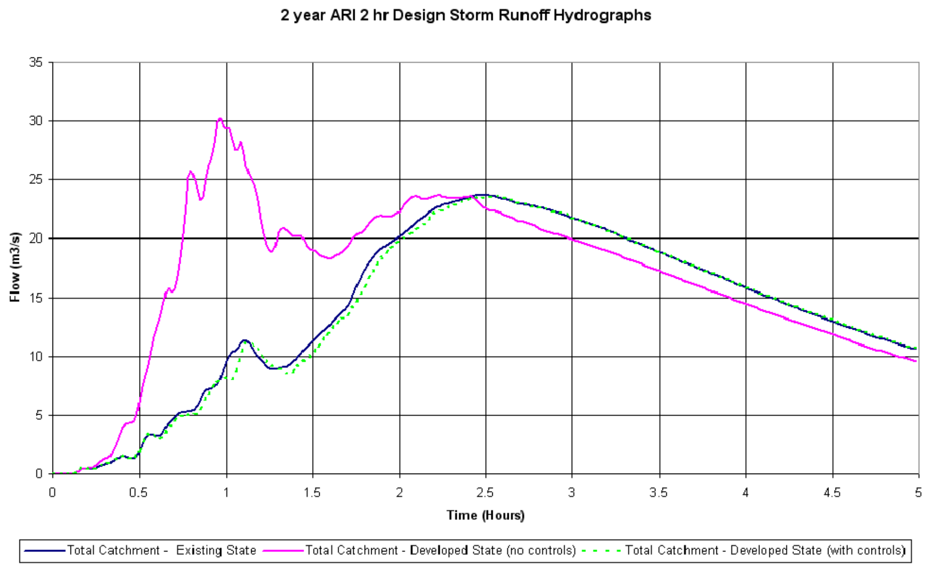
100 year ARI 9 hr Design Storm Runoff Hydrographs
(At RAFTS Node 10.07 ~ Confluence of Bellbird & Limestone Creek)

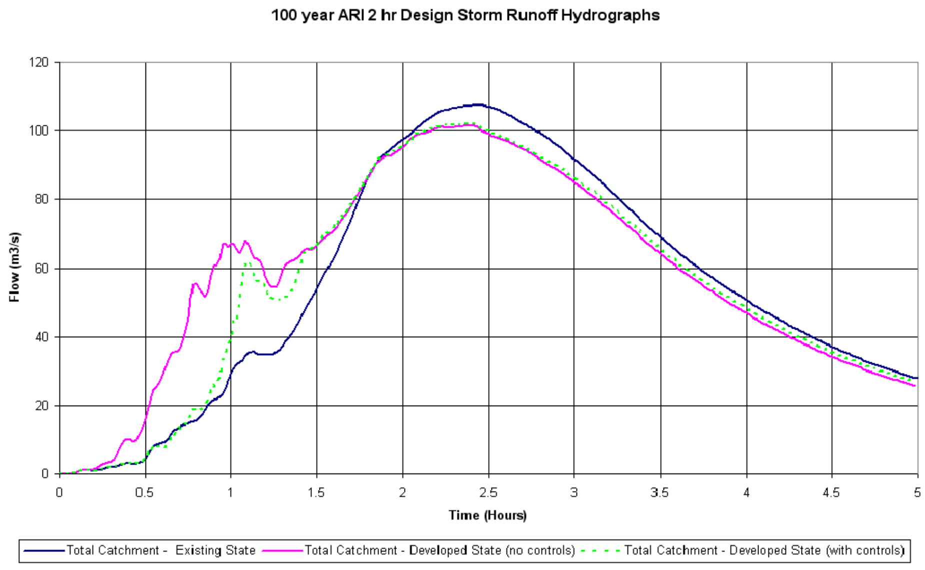


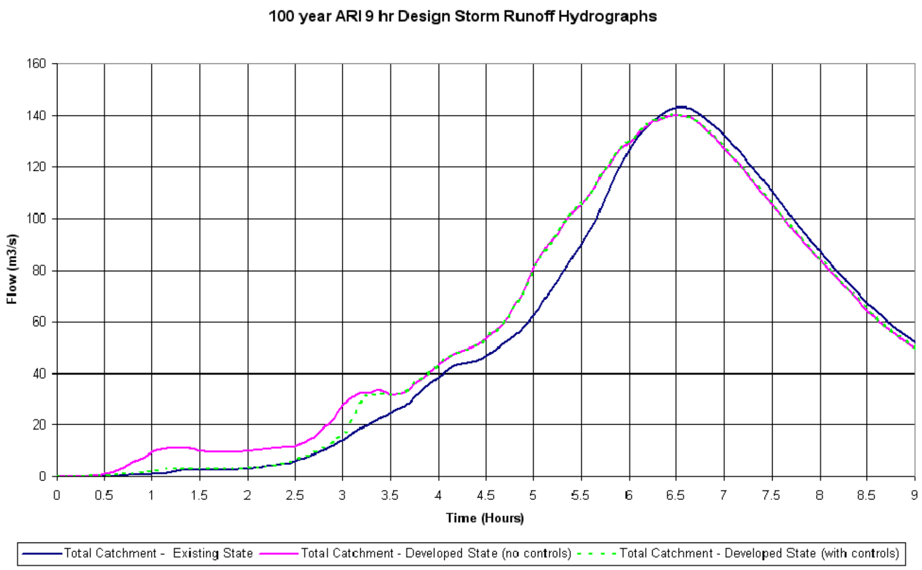
HYDROLOGIC MODEL RESULTS

FIGURE 8

FIGURE 9







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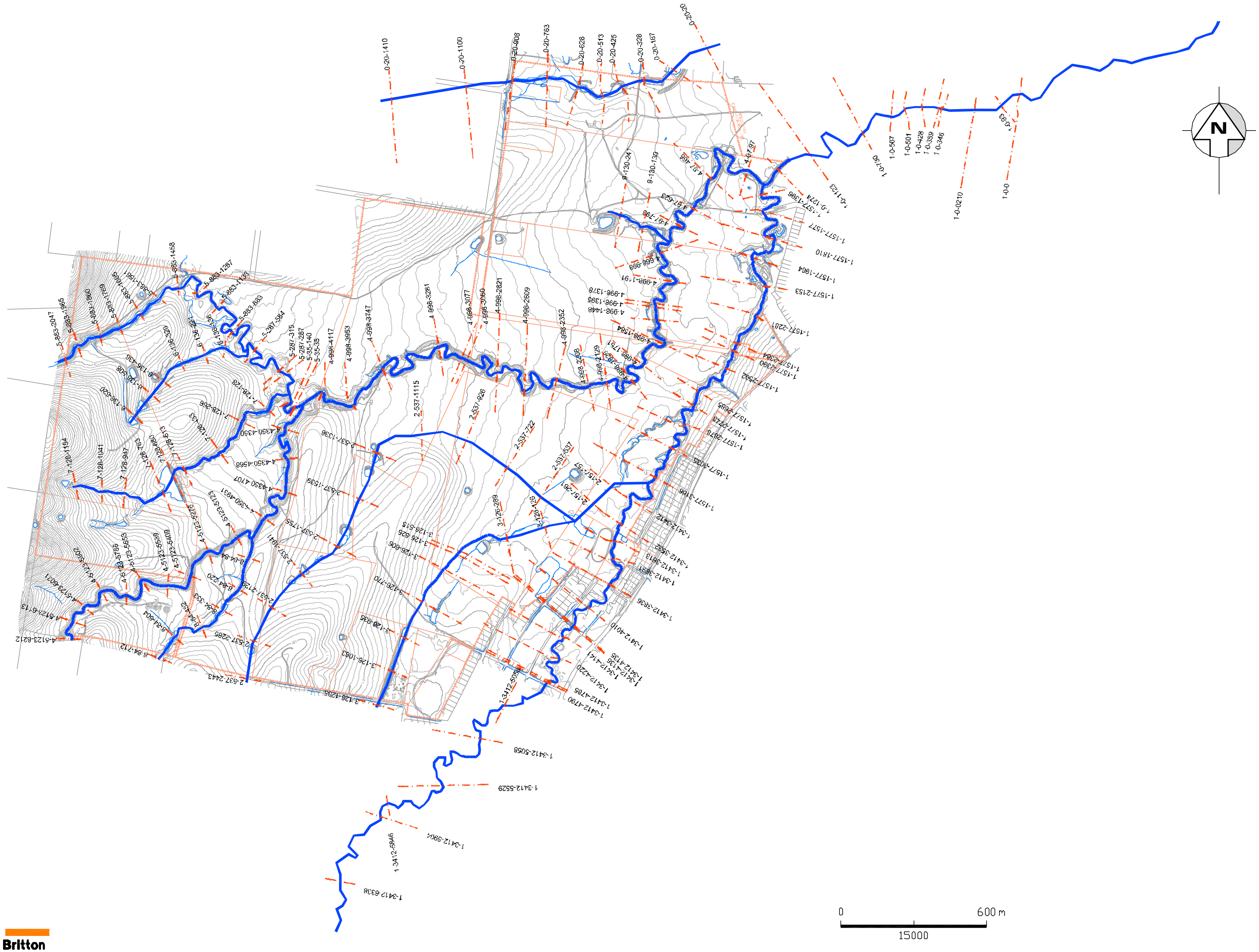
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 9 – DETEN POLICY HYD MODEL RESULTS.dwg 09/08/2007

STORMWATER MANAGEMENT POLICY
HYDROLOGIC MODEL RESULTS

FIGURE 10



HEC-RAS CROSS SECTION LOCATIONS DEVELOPED SITE

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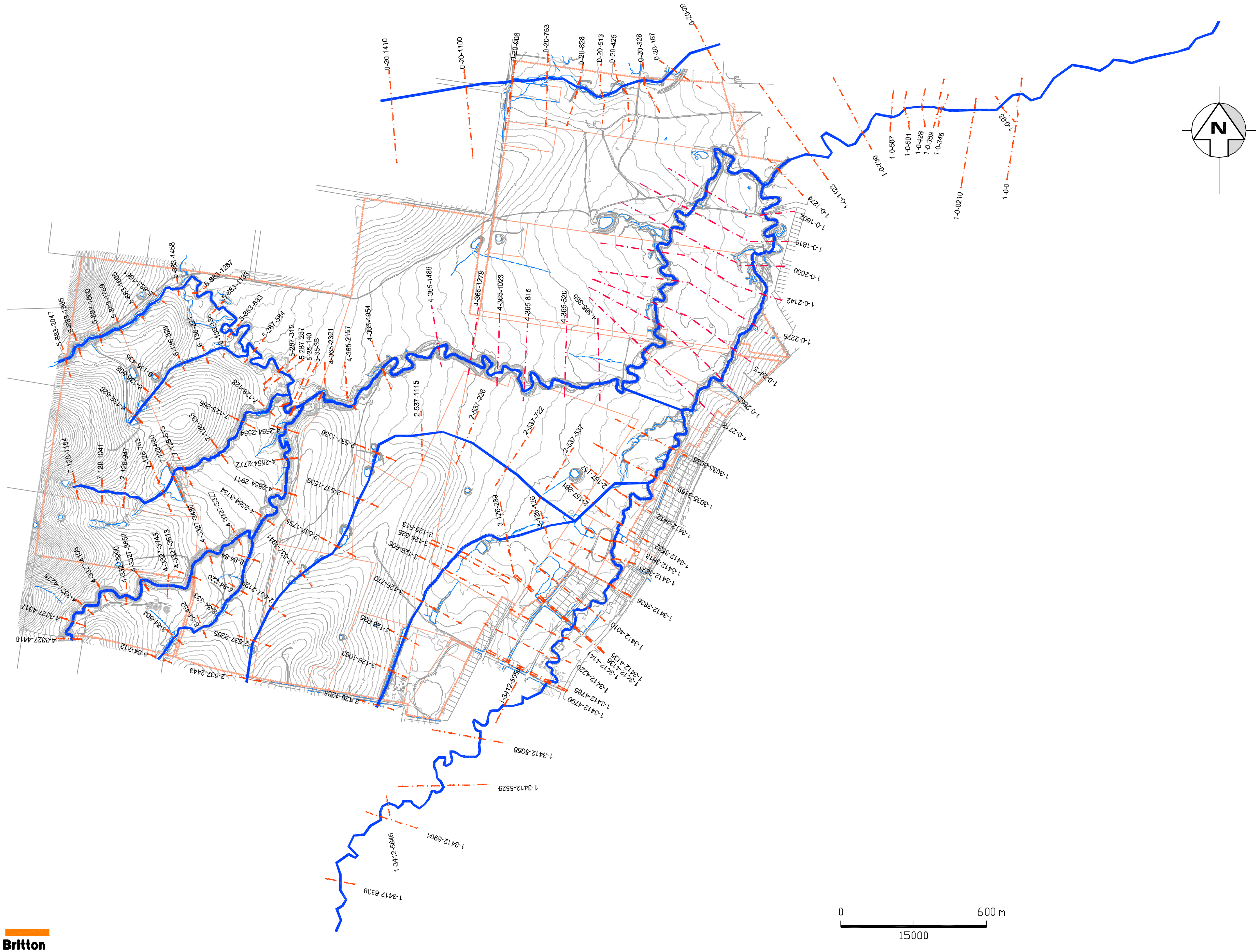
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 10 - HEC RAS SECTIONS DEVELOPED.dwg 09/08/2007

FIGURE 11



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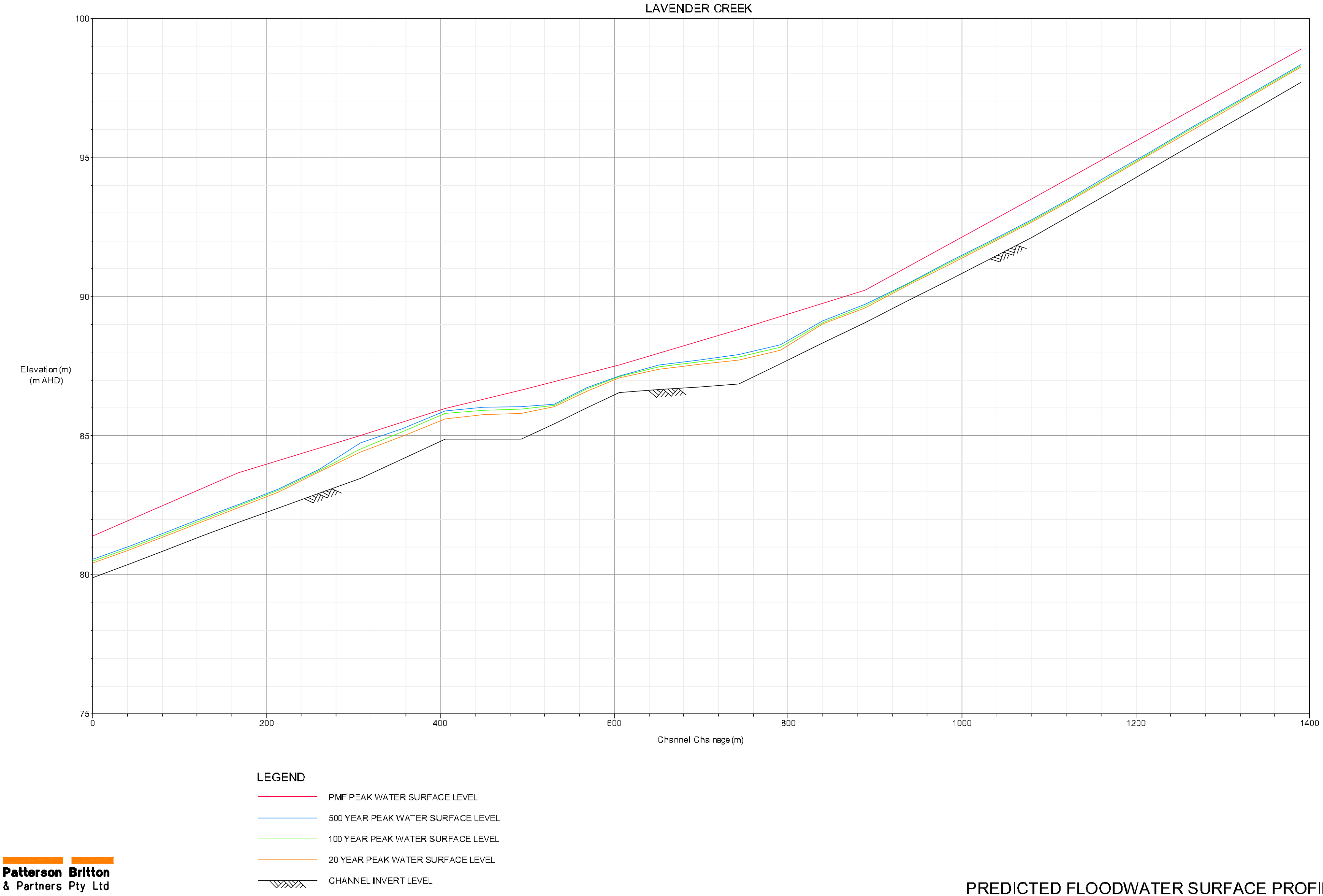
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 11 - HEC RAS SECTIONS PMF.dwg 09/08/2007

HEC RAS CROSS SECTION
LOCATIONS PMF

FIGURE 12



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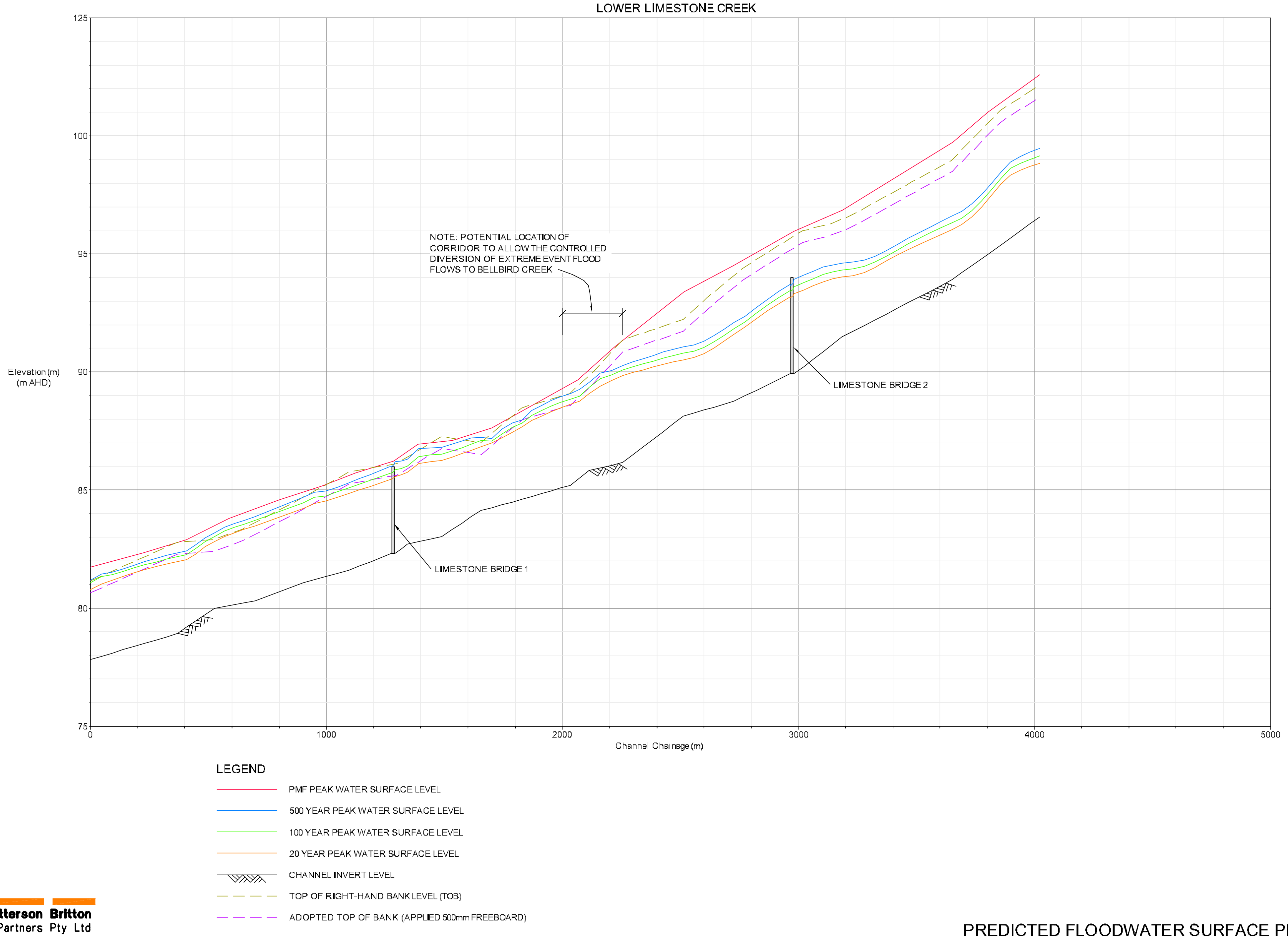
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 12 – PREDICTED FLOODWATER SURFACE PROFILE – LAVENDER CREEK.dwg 09/08/2007

PREDICTED FLOODWATER SURFACE PROFILE
LAVENDER CREEK

FIGURE 13



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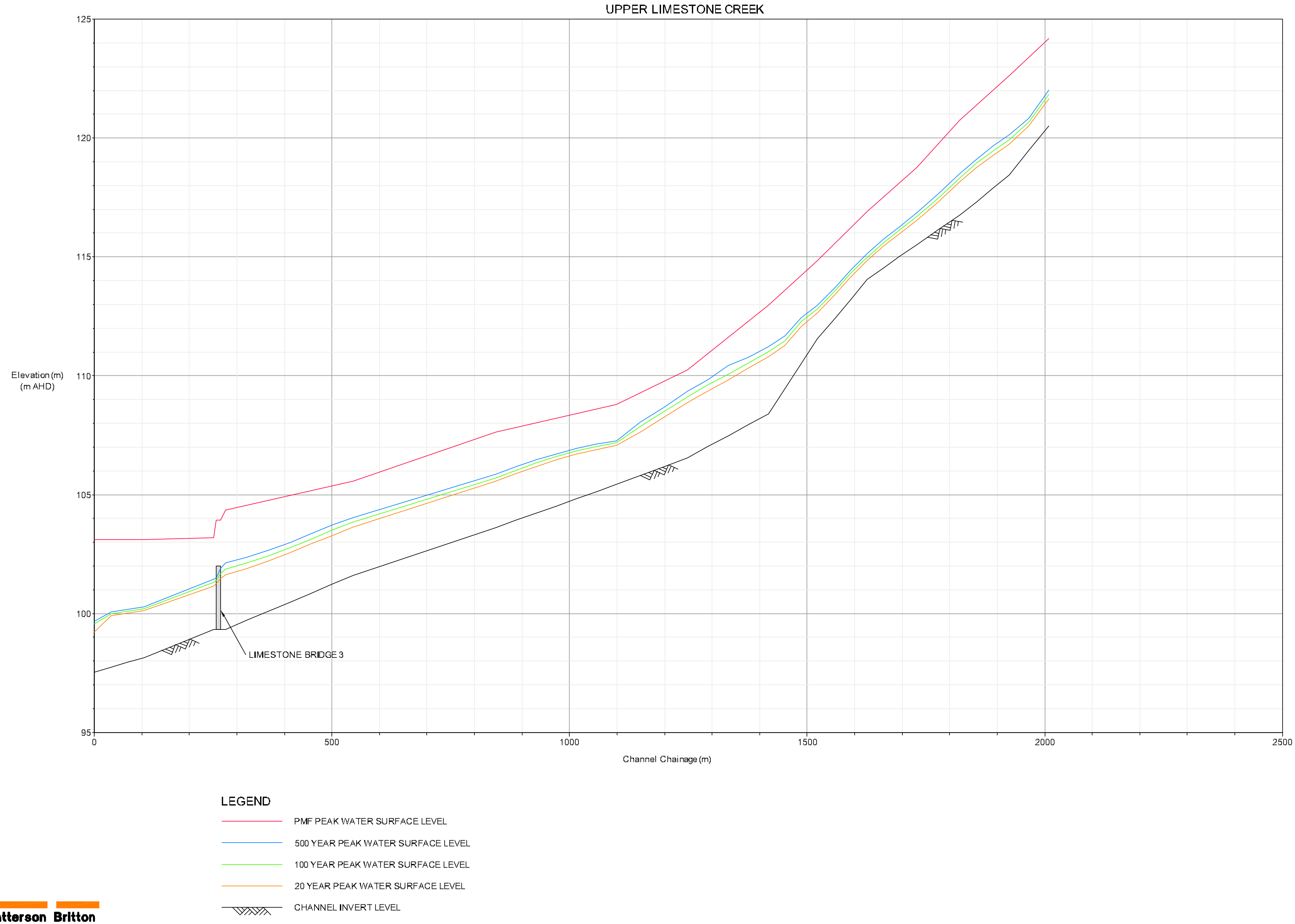
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 13 – PREDICTED FLOODWATER SURFACE PROFILE – LOWER LIMESTONE CREEK.dwg 09/08/2007

PREDICTED FLOODWATER SURFACE PROFILE
LOWER LIMESTONE CREEK



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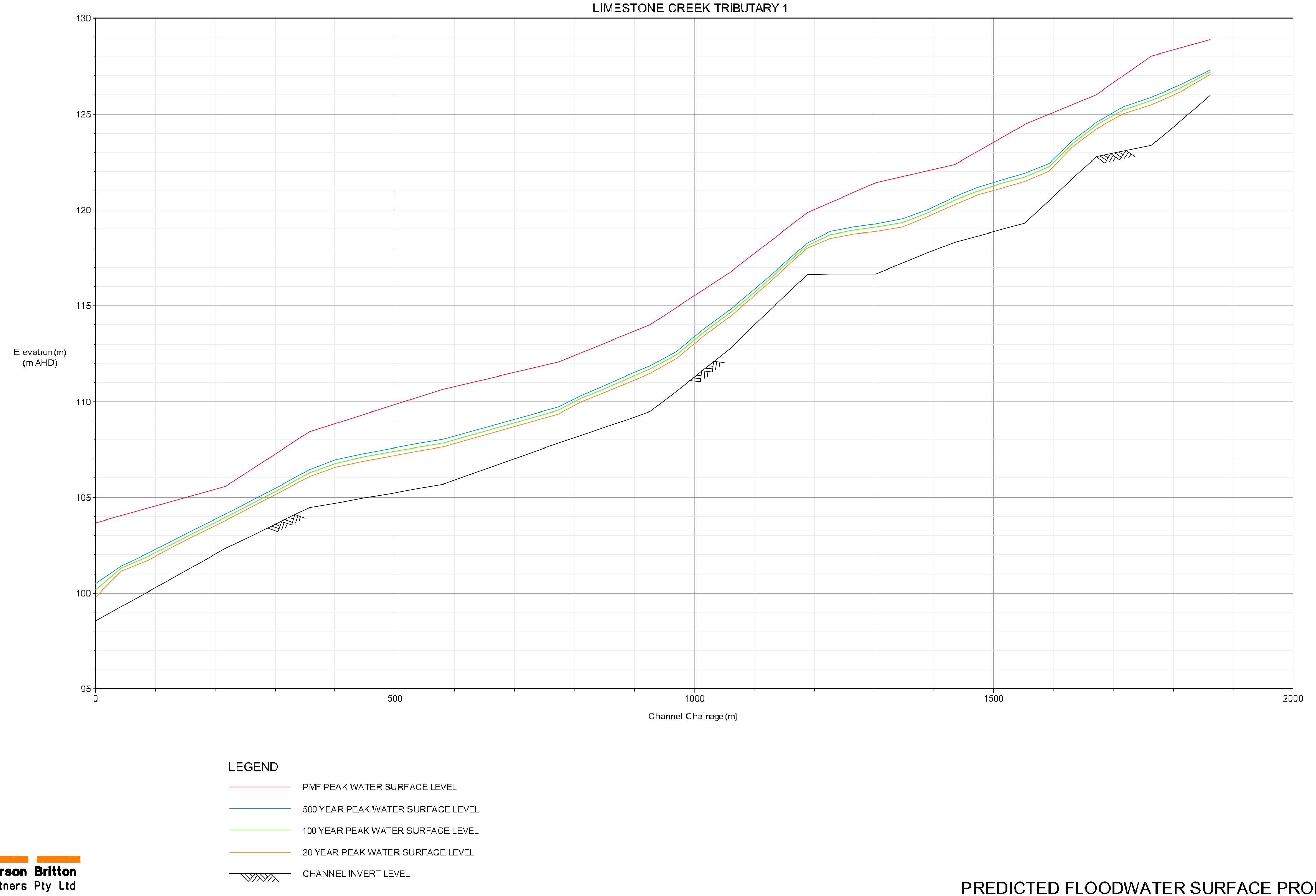
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 14 – PREDICTED FLOODWATER SURFACE PROFILE – UPPER LIMESTONE CREEK.dwg 09/08/2007

PREDICTED FLOODWATER SURFACE PROFILE
UPPER LIMESTONE CREEK

FIGURE 15



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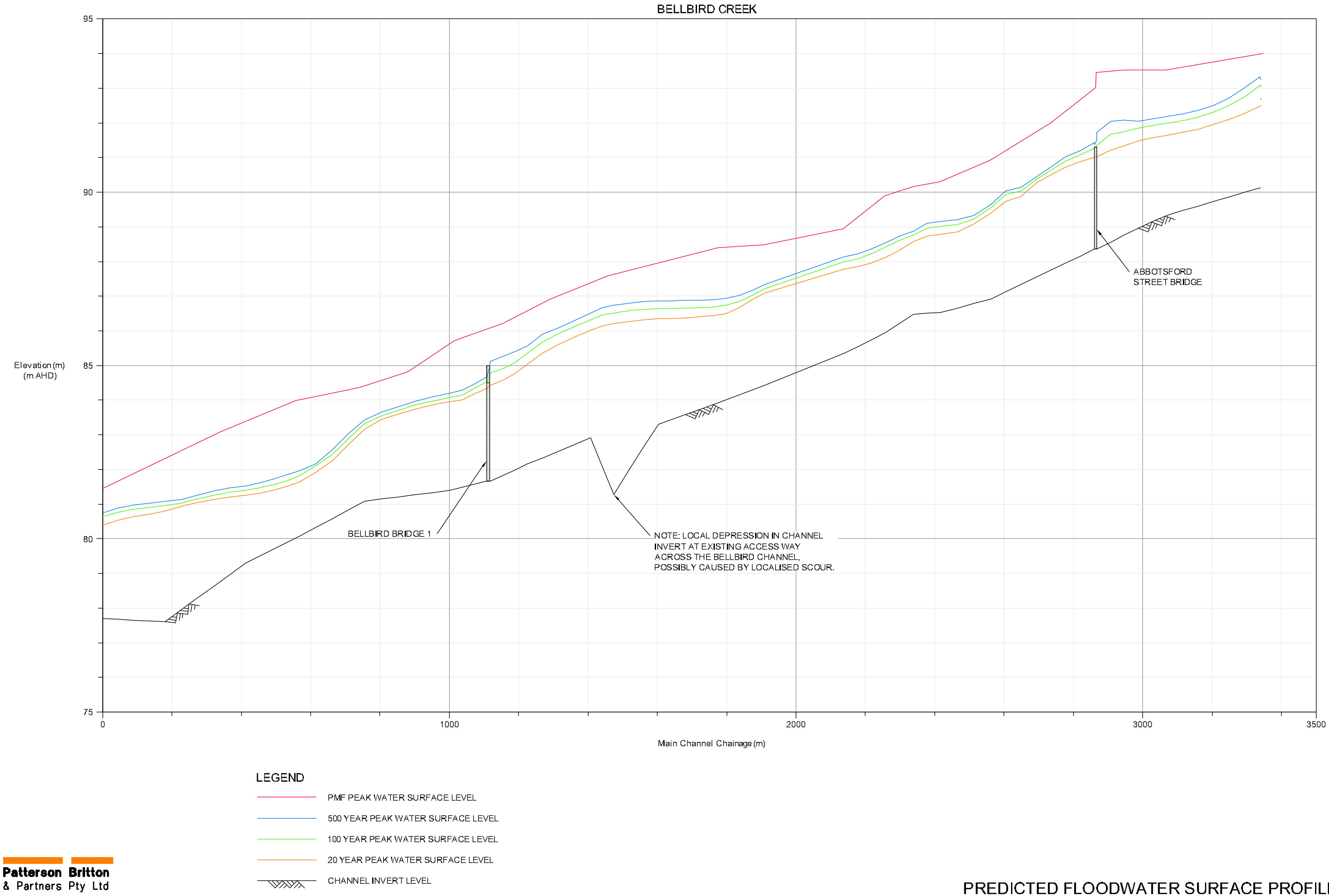
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 15 – PREDICTED FLOODWATER SURFACE PROFILE – LIMESTONE CREEK.dwg 09/08/2007

PREDICTED FLOODWATER SURFACE PROFILE
LIMESTONE CREEK TRIBUTARY 1



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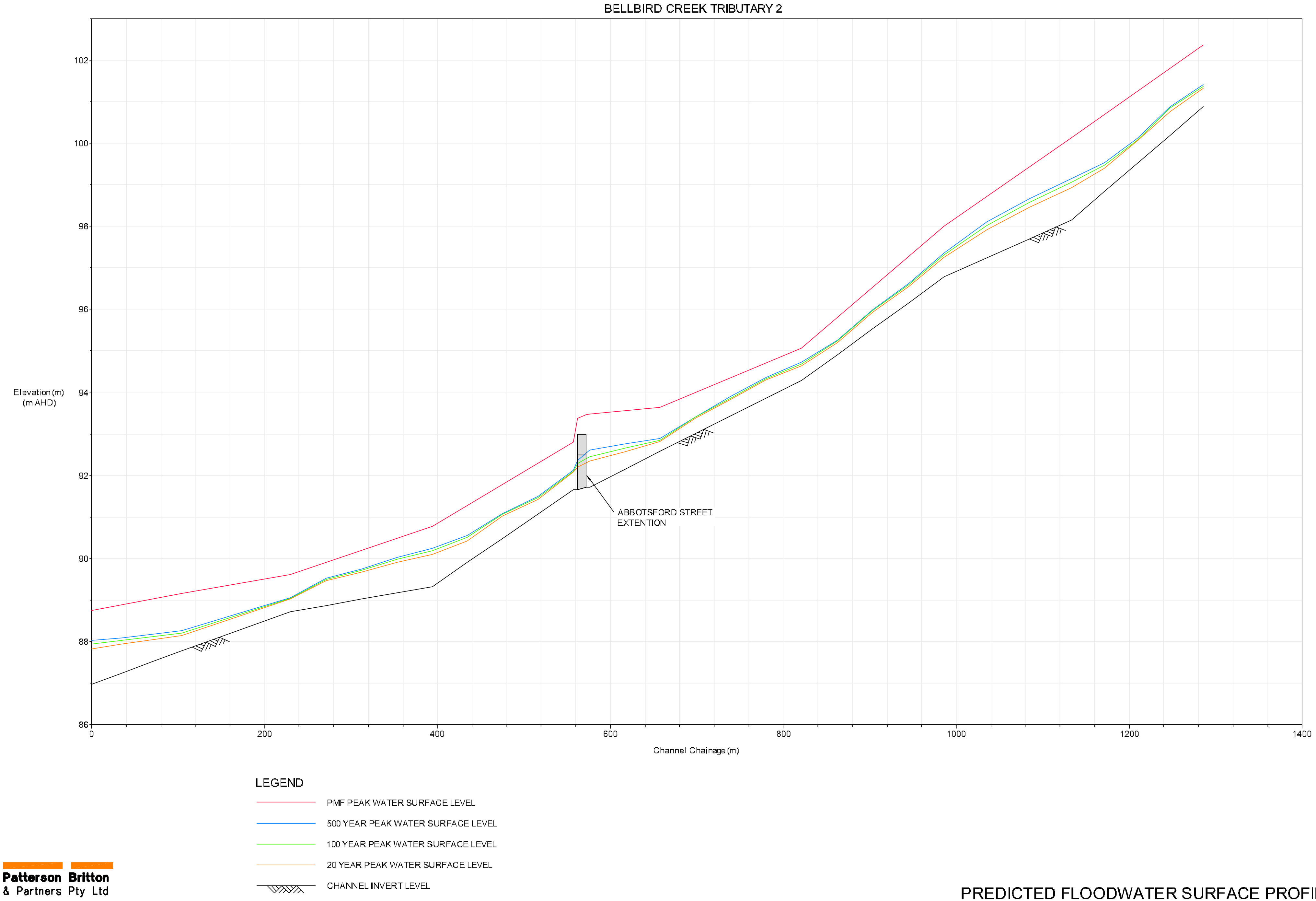
PREDICTED FLOODWATER SURFACE PROFILE
BELLBIRD CREEK

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 16 – PREDICTED FLOODWATER SURFACE PROFILE – BELLBIRD CREEK TRIB 1.dwg 09/08/2007

FIGURE 17



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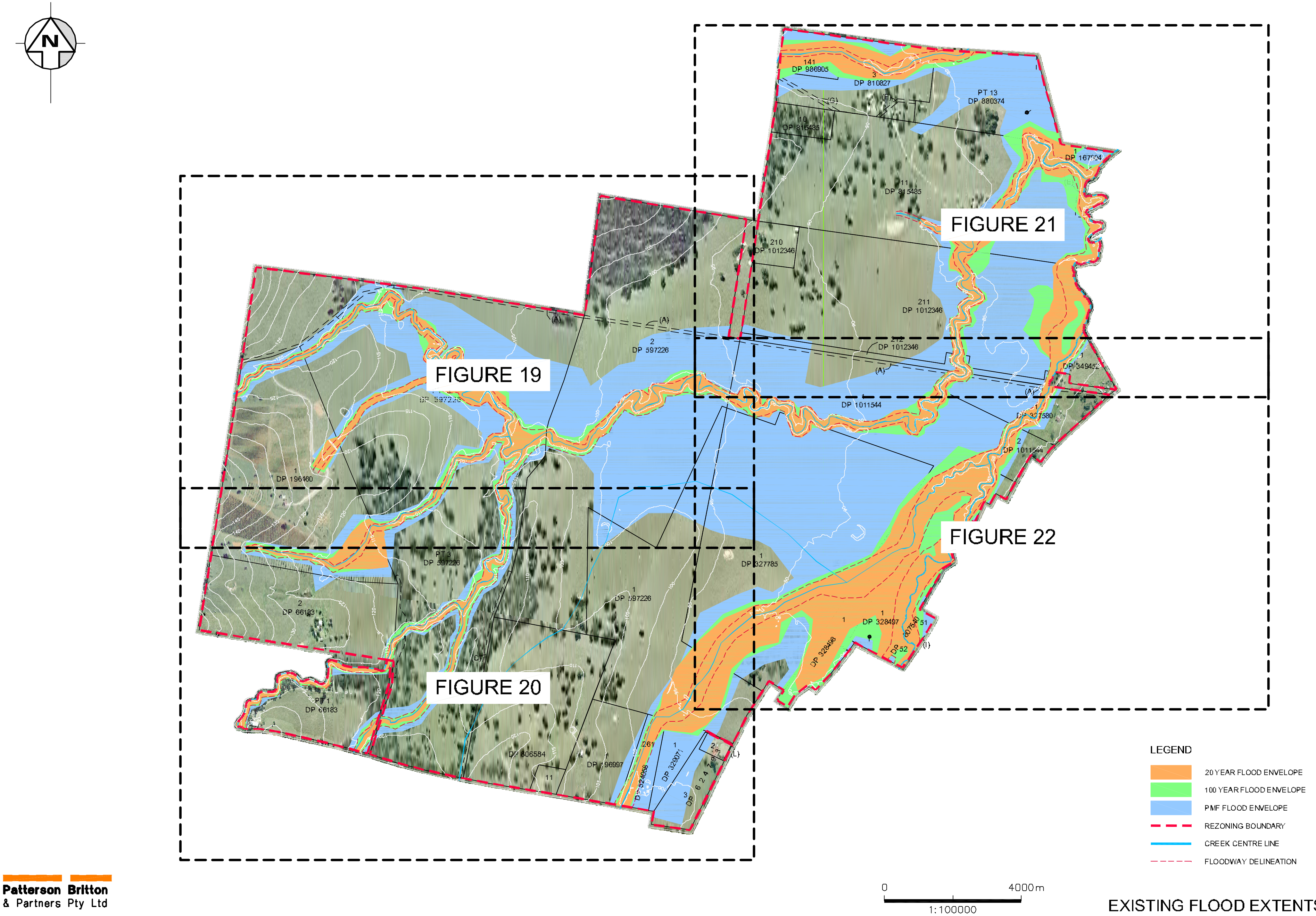
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 17 – PREDICTED FLOODWATER SURFACE PROFILE – BELLBIRD CREEK TRIB 2.dwg 09/08/2007

PREDICTED FLOODWATER SURFACE PROFILE
BELLBIRD CREEK TRIBUTARY 2



EXISTING FLOOD EXTENTS KEY PLAN

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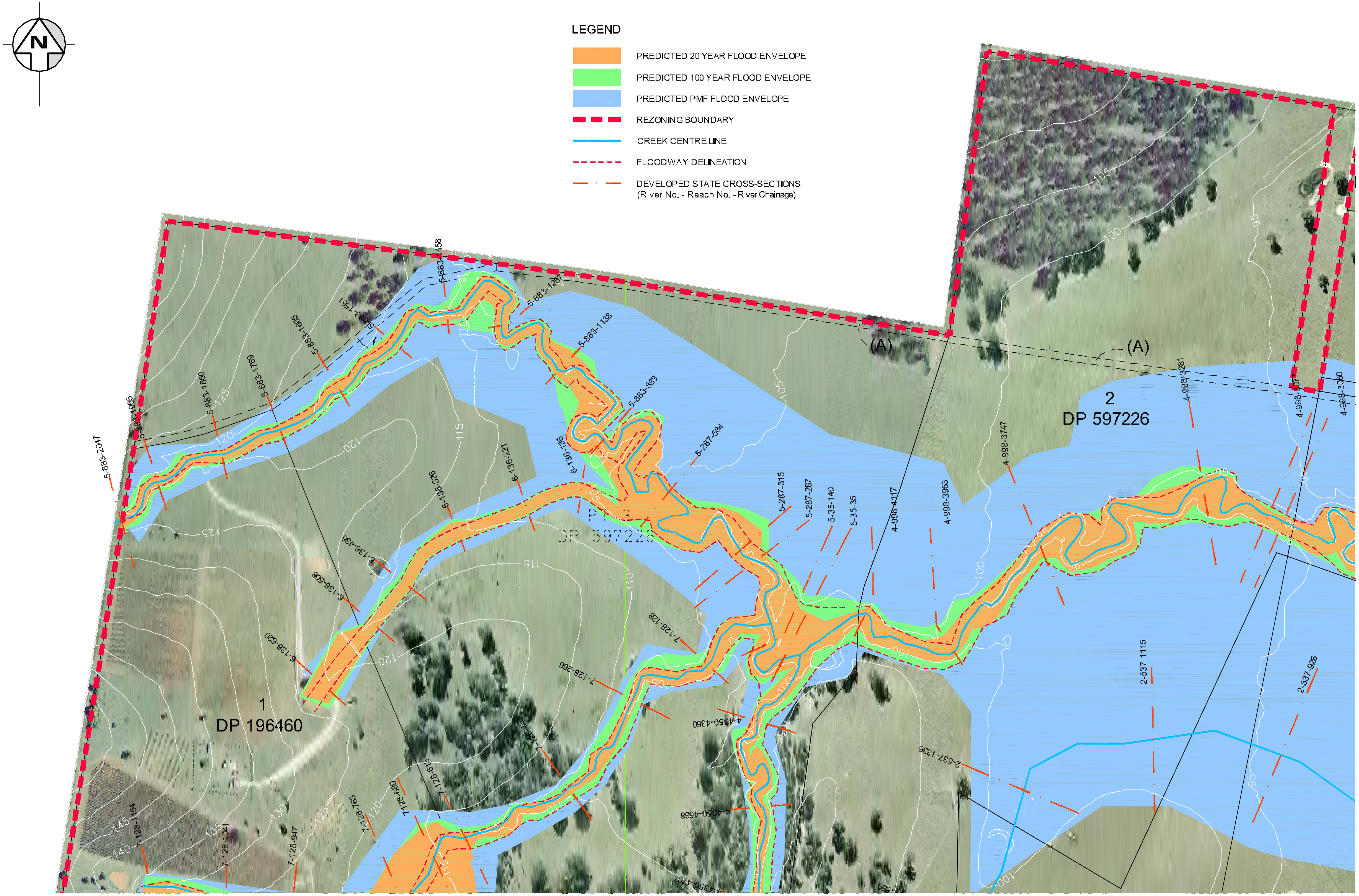
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 18-22 - EXISTING FLOOD EXTENTS.dwg 09/08/2007

FIGURE 19



0
200m
1:5000

EXISTING FLOOD EXTENTS
SHEET 1

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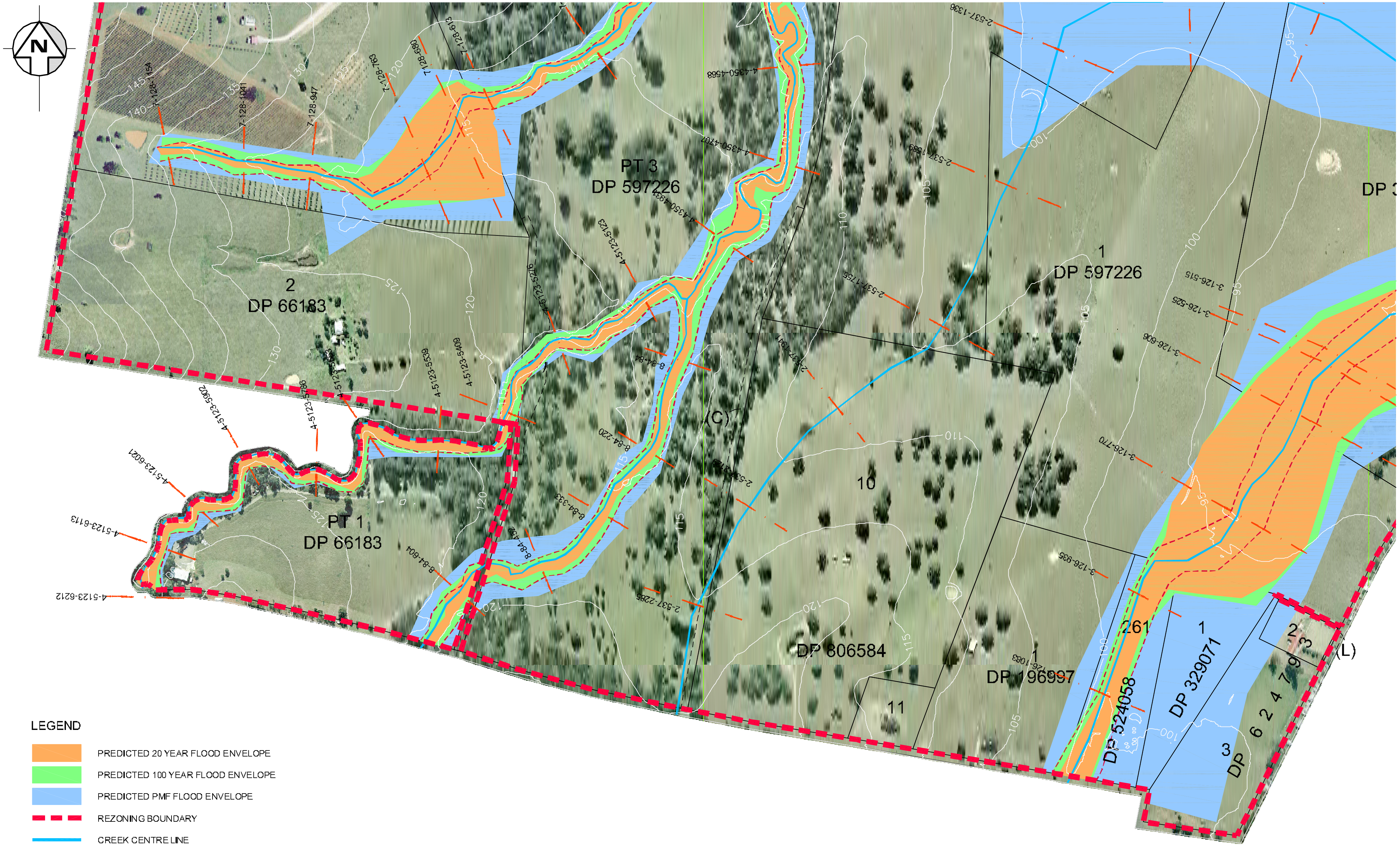
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 18-22 – EXISTING FLOOD EXTENTS.dwg 09/08/2007

FIGURE 20



LEGEND

- PREDICTED 20 YEAR FLOOD ENVELOPE
- PREDICTED 100 YEAR FLOOD ENVELOPE
- PREDICTED PMF FLOOD ENVELOPE
- REZONING BOUNDARY
- CREEK CENTRE LINE
- FLOODWAY DELINEATION
- DEVELOPED STATE CROSS-SECTIONS (River No. - Reach No. - River Chainage)

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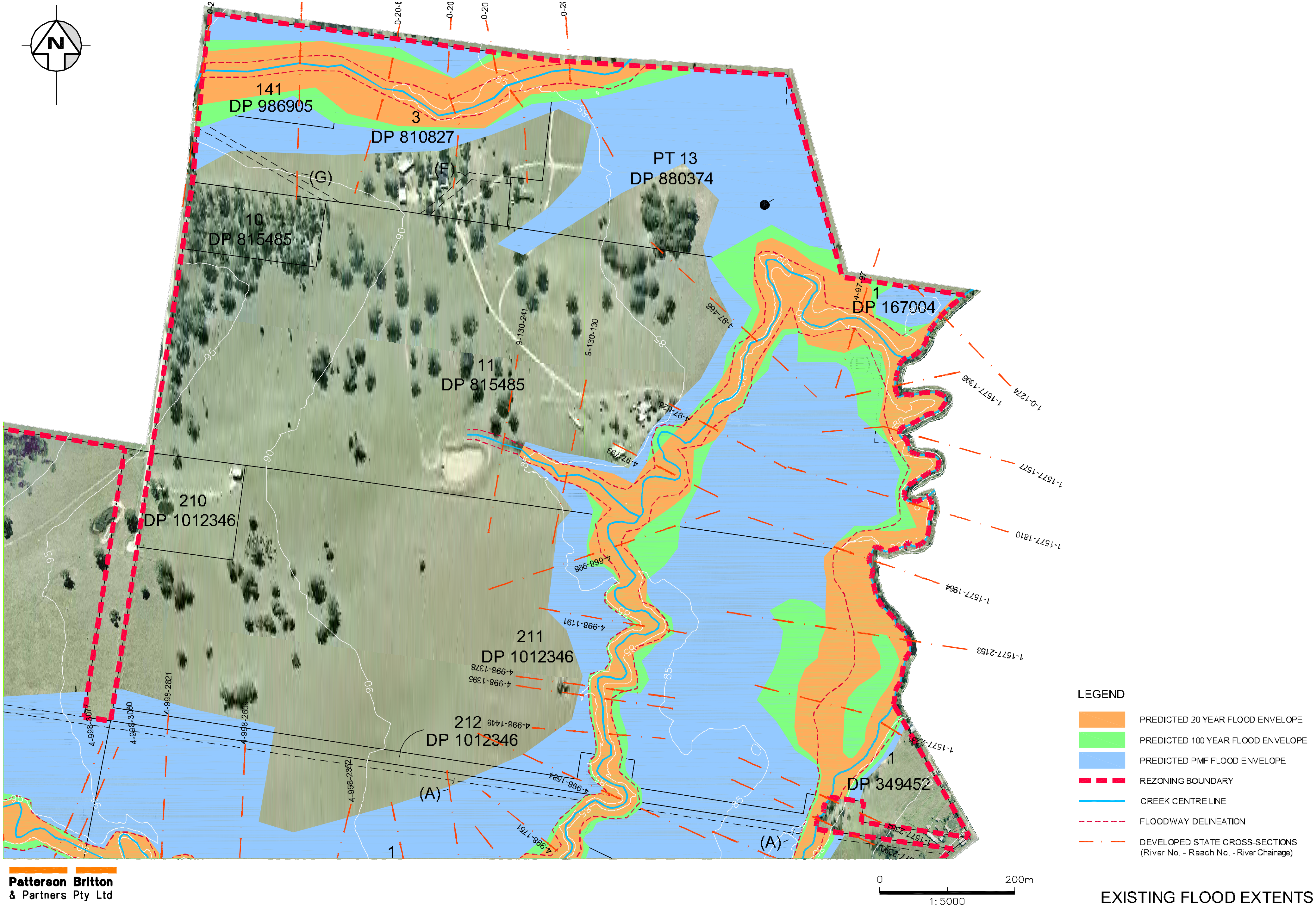
0 200m
1:5000

EXISTING FLOOD EXTENTS
SHEET 2

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 18–22 – EXISTING FLOOD EXTENTS.dwg 09/08/2007

FIGURE 21



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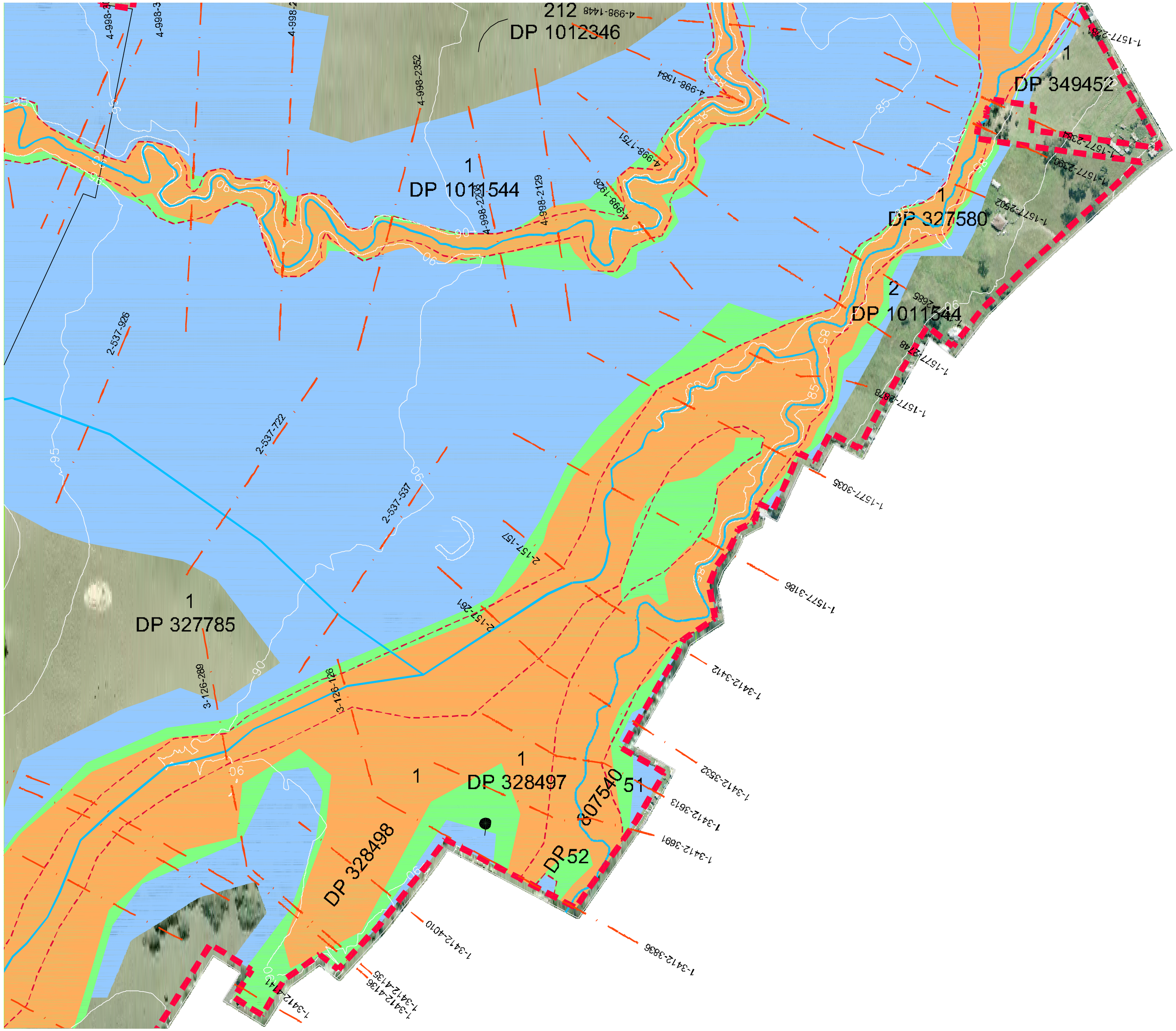
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 18-22 – EXISTING FLOOD EXTENTS.dwg 09/08/2007

EXISTING FLOOD EXTENTS
SHEET 3

FIGURE 22



LEGEND

- PREDICTED 20 YEAR FLOOD ENVELOPE
- PREDICTED 100 YEAR FLOOD ENVELOPE
- PREDICTED PMF FLOOD ENVELOPE
- REZONING BOUNDARY
- CREEK CENTRE LINE
- FLOODWAY DELINEATION
- DEVELOPED STATE CROSS-SECTIONS (River No. - Reach No. - River Chainage)

0 200m
1:5000

EXISTING FLOOD EXTENTS
SHEET 4

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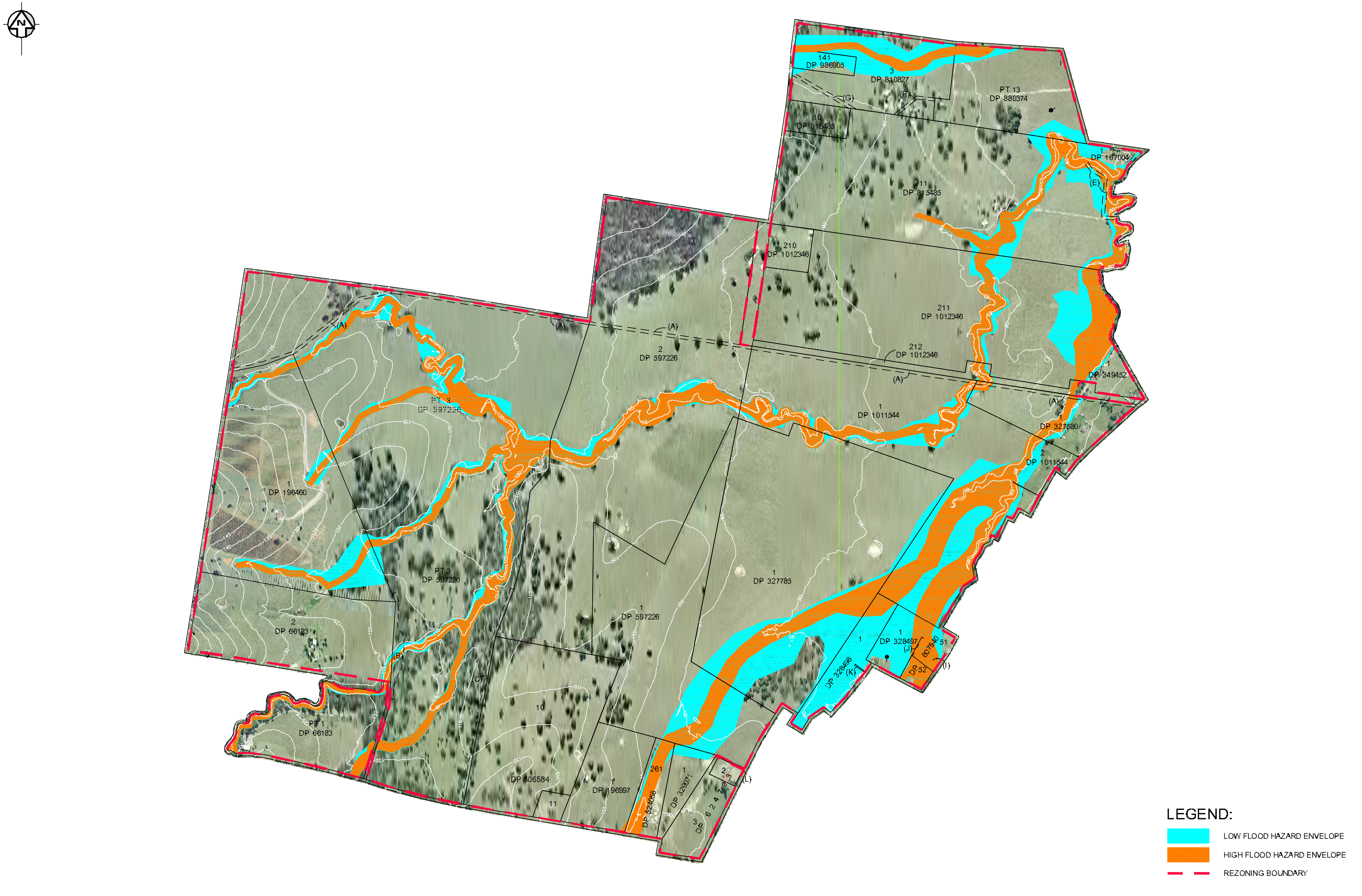
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 18-22 – EXISTING FLOOD EXTENTS.dwg 09/08/2007

FIGURE 23



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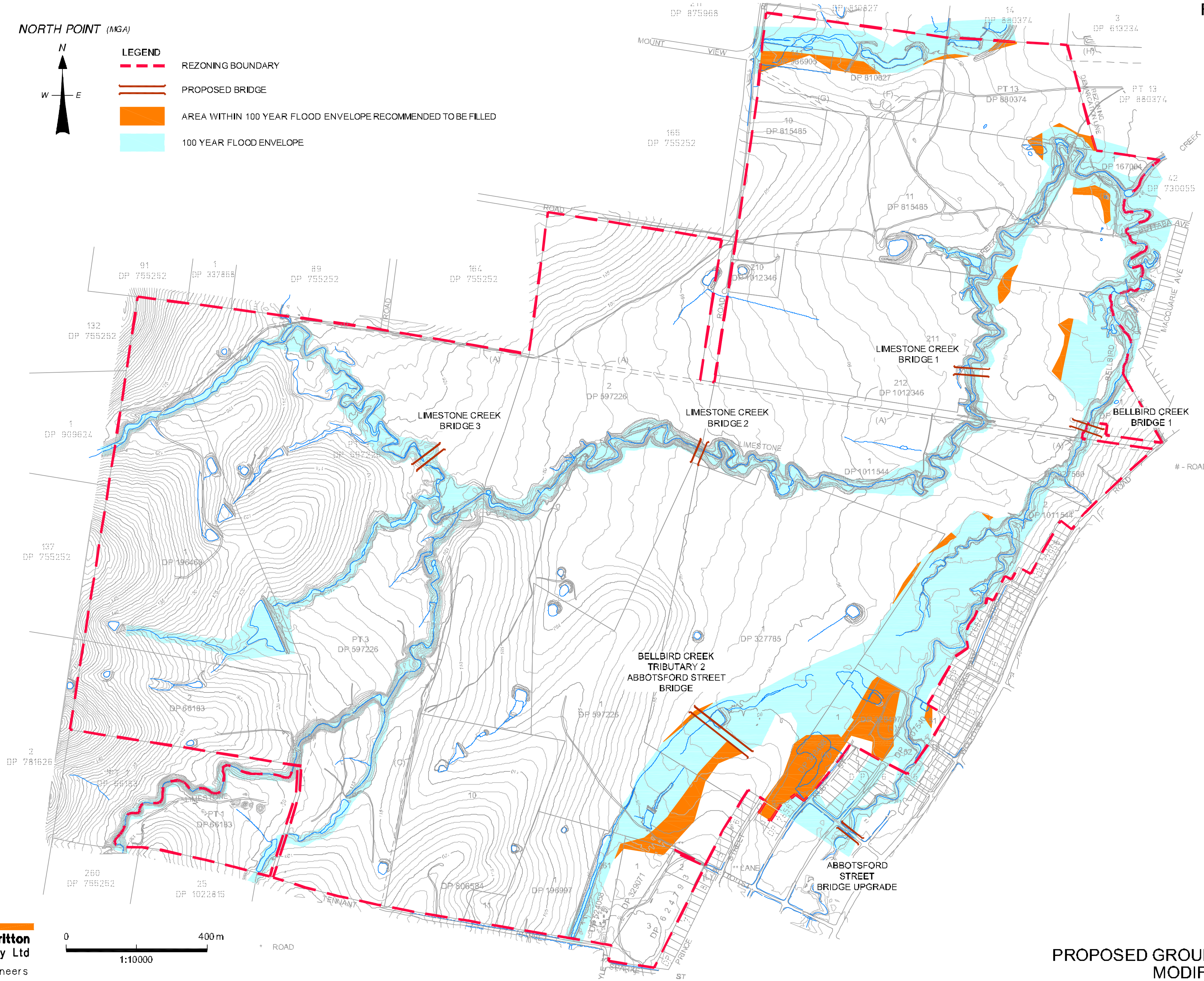
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 23 – PREDICTED FLOOD HAZARD.dwg 09/08/2007

PREDICTED FLOOD HAZARD
CATEGORISED FOR 100yr ARI FLOOD EVENT

FIGURE 24



PROPOSED GROUND LEVEL MODIFICATIONS

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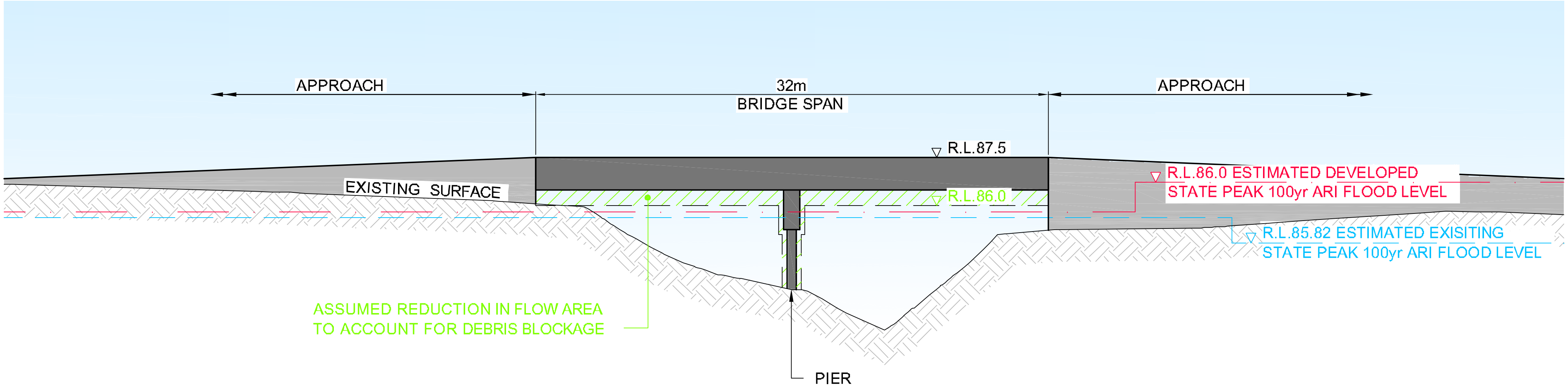
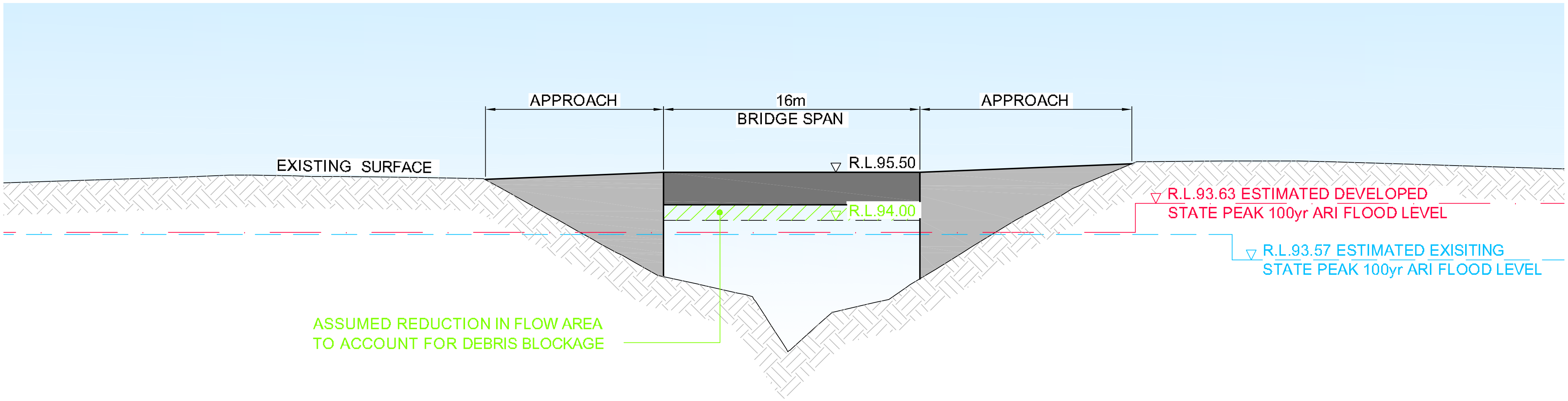
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 24 - PROP GROUND LEVEL MOD.DWG 09/08/2007

FIGURE 25



ELEVATION OF LIMESTONE CREEK BRIDGE 1 LOOKING DOWNSTREAM

SCALE 1:250 - 1 x HORIZ
- 2 x VERT



ELEVATION OF LIMESTONE CREEK BRIDGE 2 LOOKING DOWNSTREAM

SCALE 1:250 - 1 x HORIZ
- 2 x VERT

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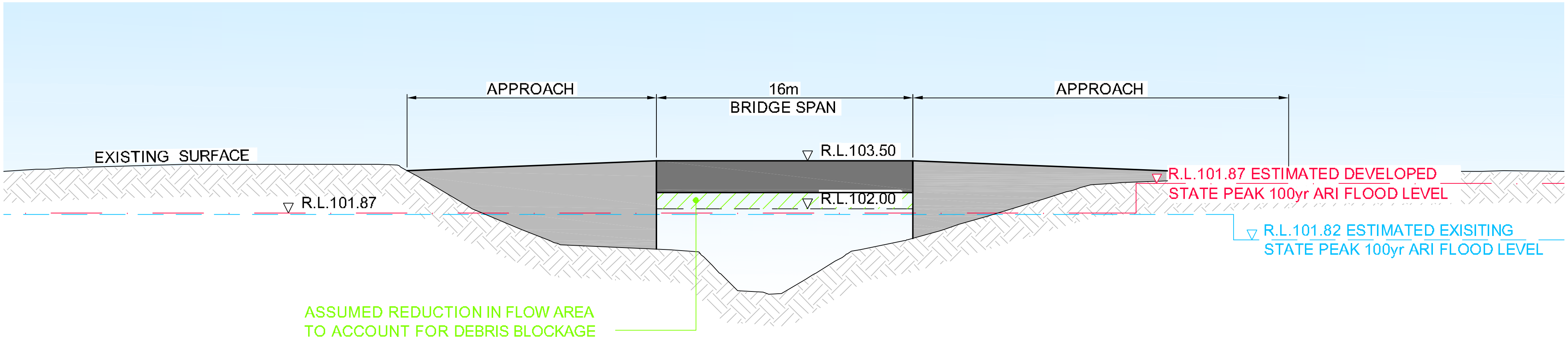
LIMESTONE CREEK BRIDGE 1 AND
LIMESTONE CREEK BRIDGE 2
CONCEPTUAL LAYOUT

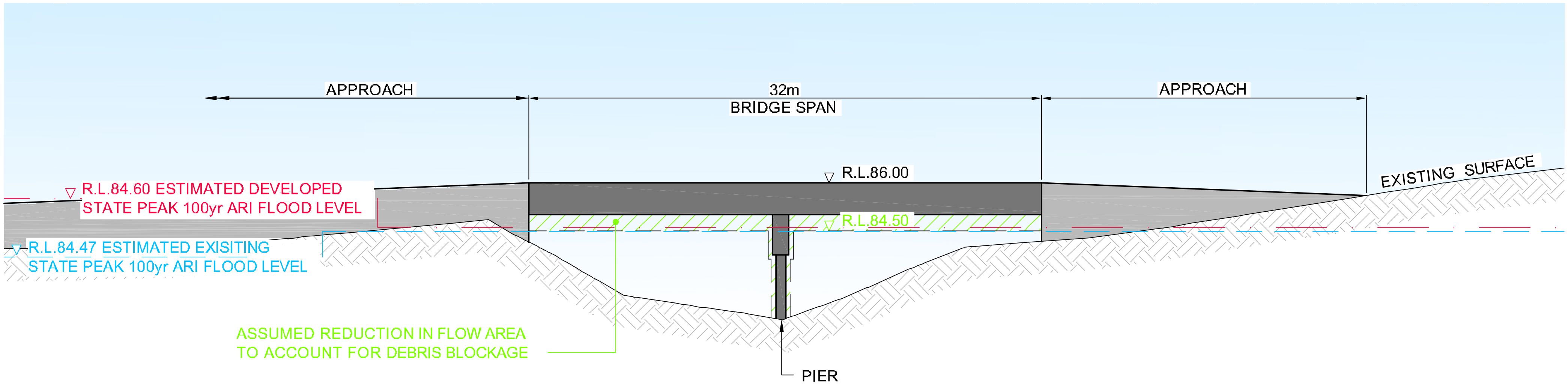
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 25 – CONCEPT BRIDGE PROFILE LIMESTONE CR BR1 & LIMESTONE CK BR2.dwg 09/08/2007

FIGURE 26



ELEVATION OF LIMESTONE CREEK BRIDGE 3 LOOKING DOWNSTREAM

SCALE 1:250 - 1 x HORIZ
- 2 x VERT



ELEVATION OF BELLBIRD CREEK BRIDGE 1 LOOKING DOWNSTREAM

SCALE 1:250 - 1 x HORIZ
- 2 x VERT

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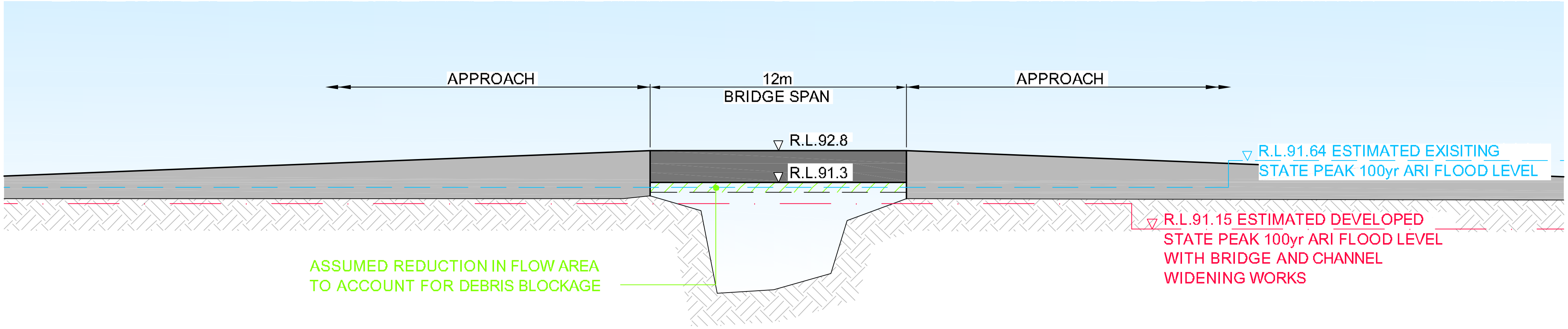
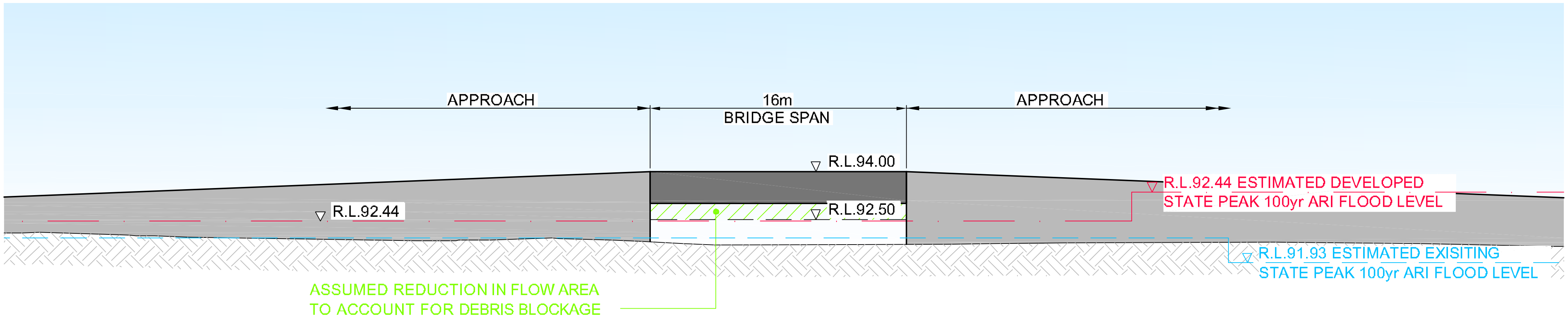
LIMESTONE CREEK BRIDGE 3 AND
BELLBIRD CREEK BRIDGE 1
CONCEPTUAL LAYOUT

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 26 – CONCEPT BRIDGE PROFILE LIMESTONE CK BR3 & BELLBIRD CK BR1.DWG 09/08/2007



ELEVATION OF BELLBIRD CREEK, ABBOTSFORD STREET BRIDGE 1 LOOKING DOWNSTREAM

N.T.S.



ELEVATION OF BELLBIRD CREEK TRIBUTARY 2, ABBOTSFORD STREET BRIDGE LOOKING DOWNSTREAM

N.T.S.

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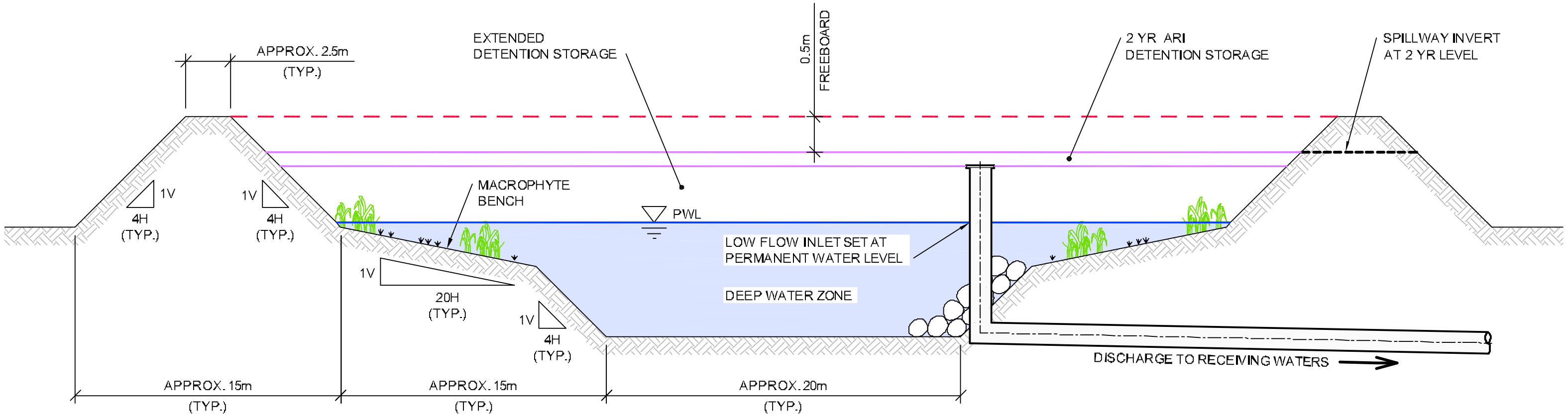
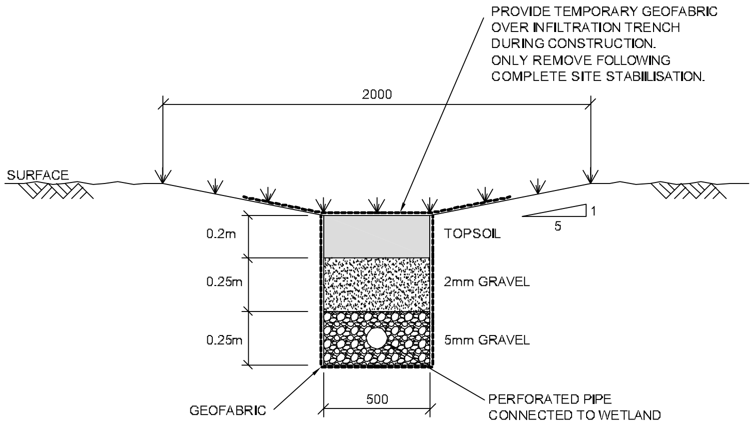
BELLBIRD CREEK, ABBOTSFORD STREET BRIDGE UPGRADE
BELLBIRD CREEK TRIBUTARY 2, ABBOTSFORD STREET BRIDGE UPGRADE
CONCEPTUAL LAYOUT

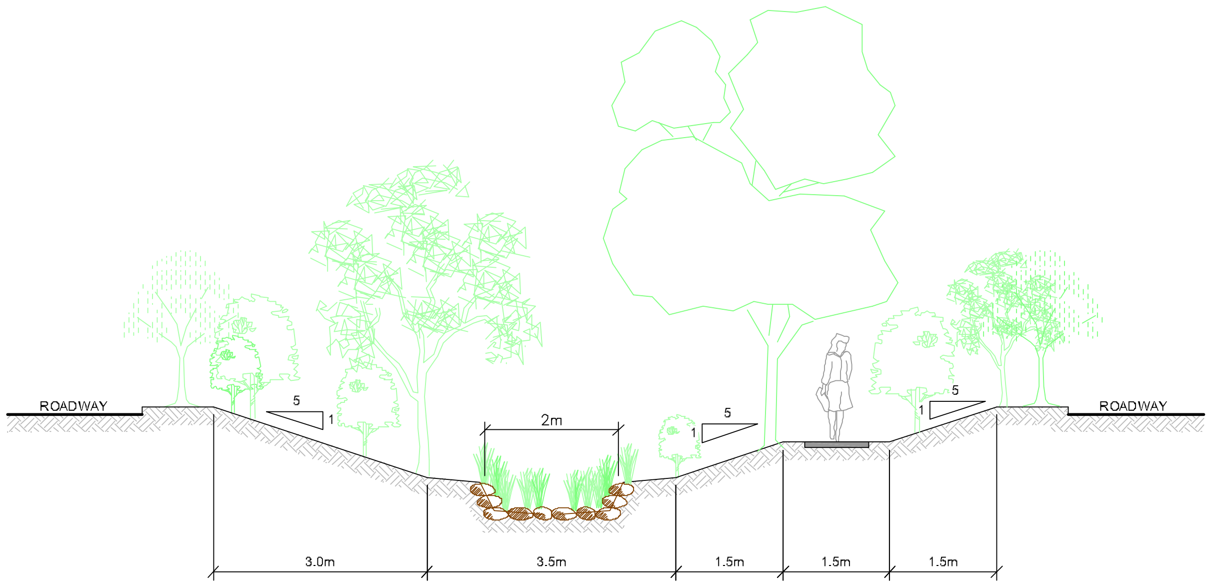
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 27 – CONCEPT BRIDGE PROFILE LIMESTONE CK BR3 & BELLBIRD CK BR1.DWG 09/08/2007



WETLAND DESIGN CONCEPT
1:300 HORIZ
1:75 VERT



VEGETATED BIO-SWALE TYPICAL SECTION
SCALE 1:20



TYPICAL OVERLAND FLOWPATH FOR URBAN AREAS
SCALE 1:75

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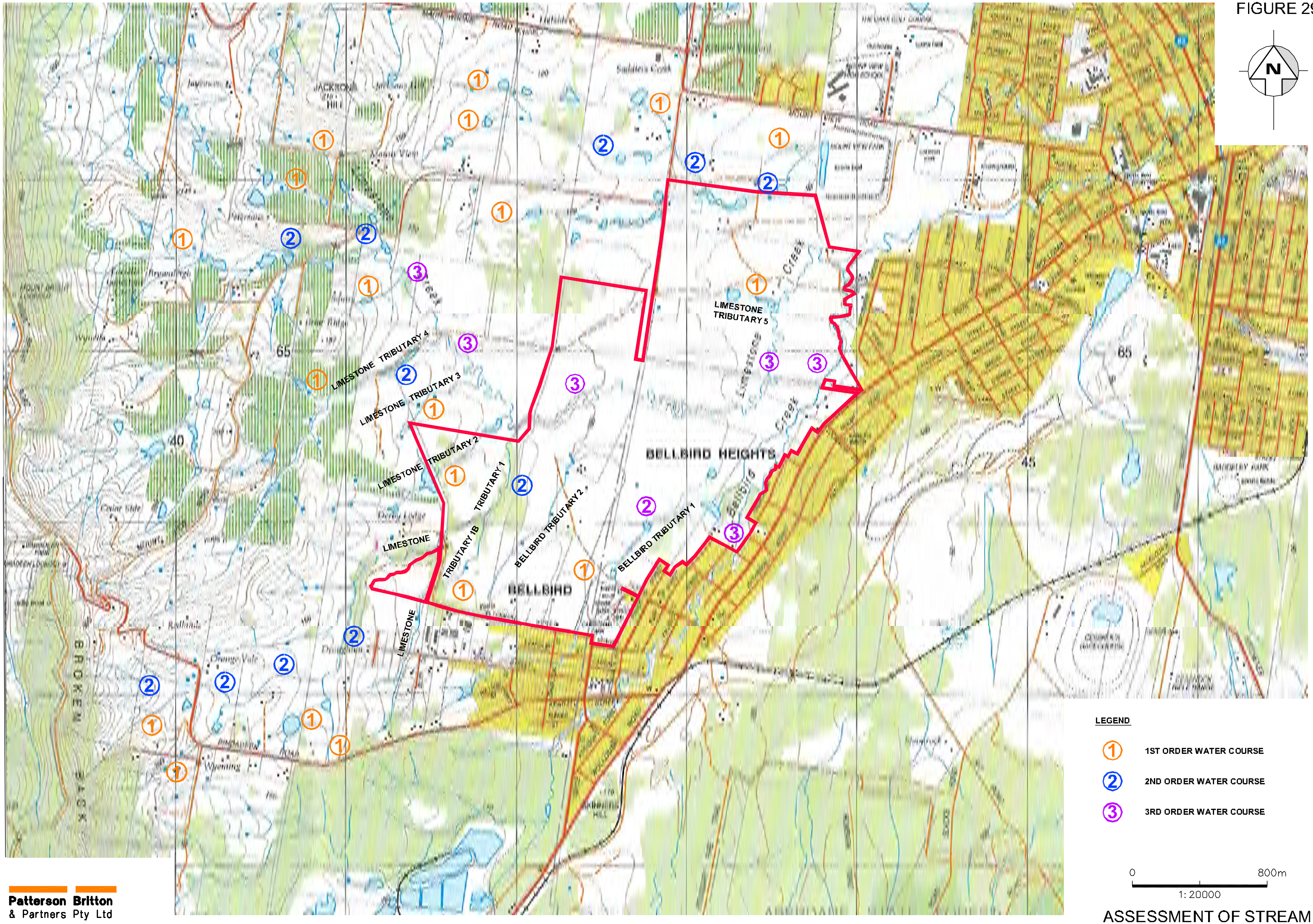
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 28 – TYPICAL STORMWATER CONTROL DETAILS.dwg 09/08/2007

TYPICAL STORMWATER
CONTROL DETAILS

FIGURE 29



ASSESSMENT OF STREAM ORDER CATEGORIES

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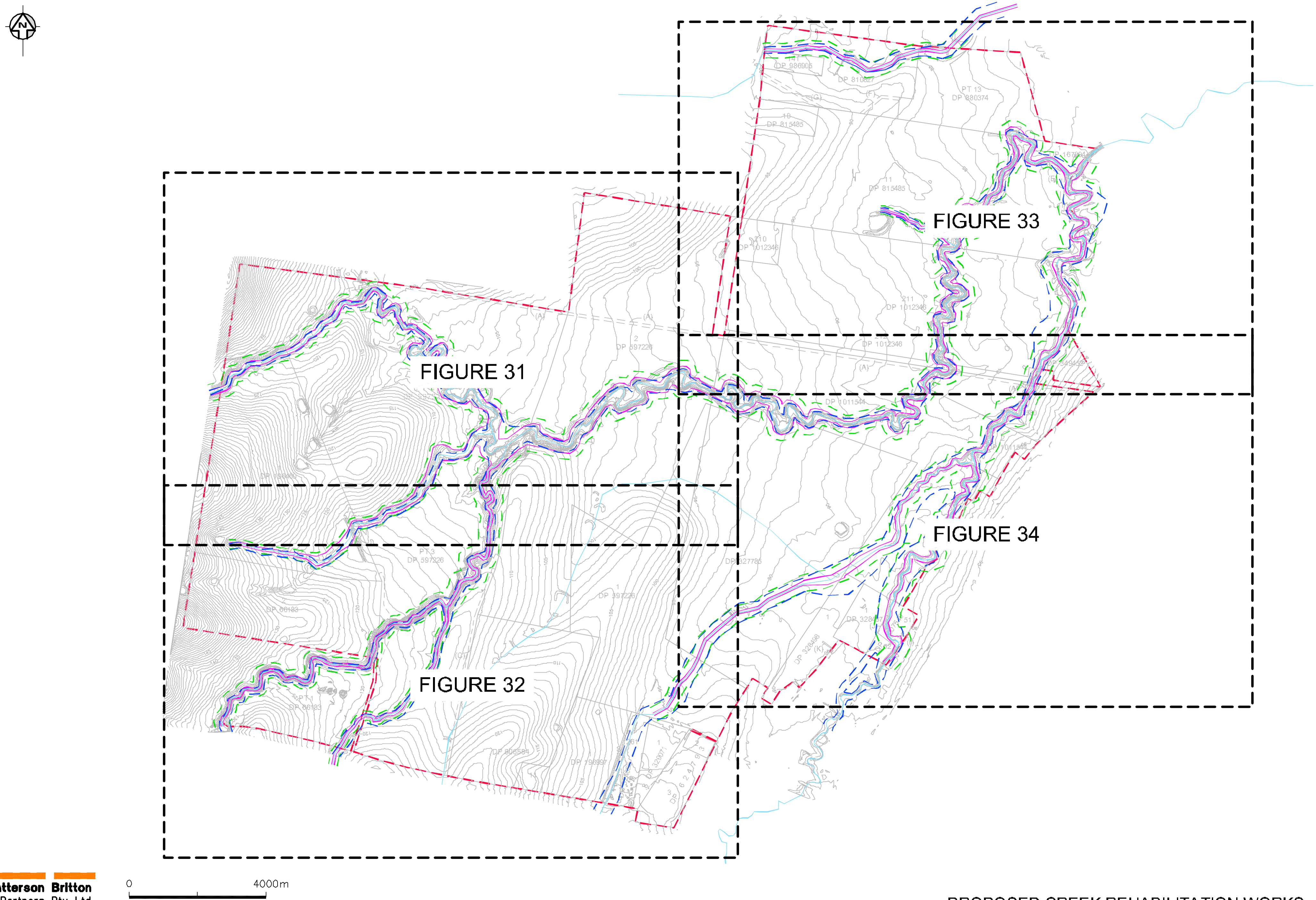
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 29 - ASSESSMENT OF STREAM ORDER.dwg 09/08/2007



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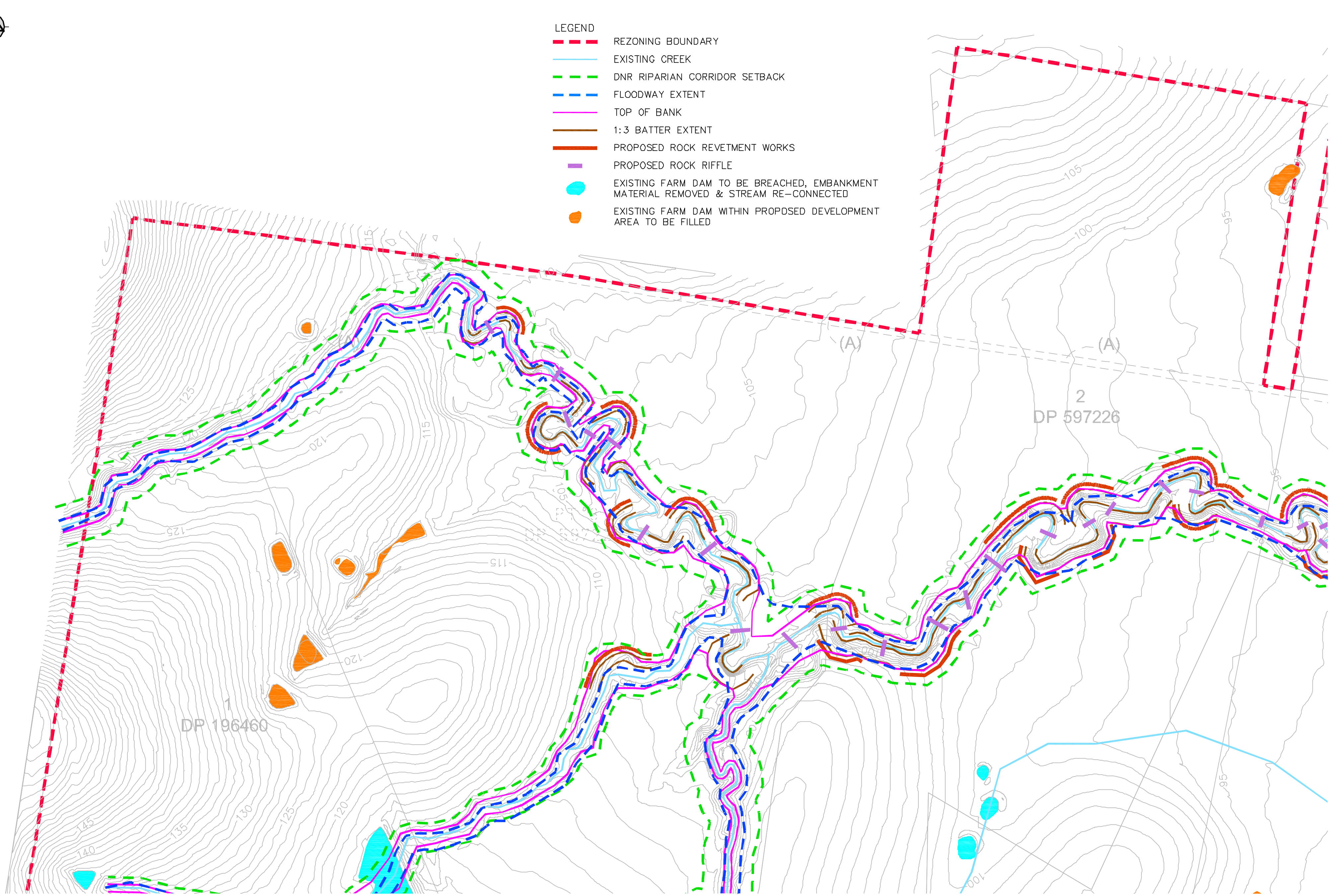
PROPOSED CREEK REHABILITATION WORKS
KEY PLAN

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 30-34 – CREEK REHAB KEY PLAN.dwg 09/08/2007

FIGURE 31



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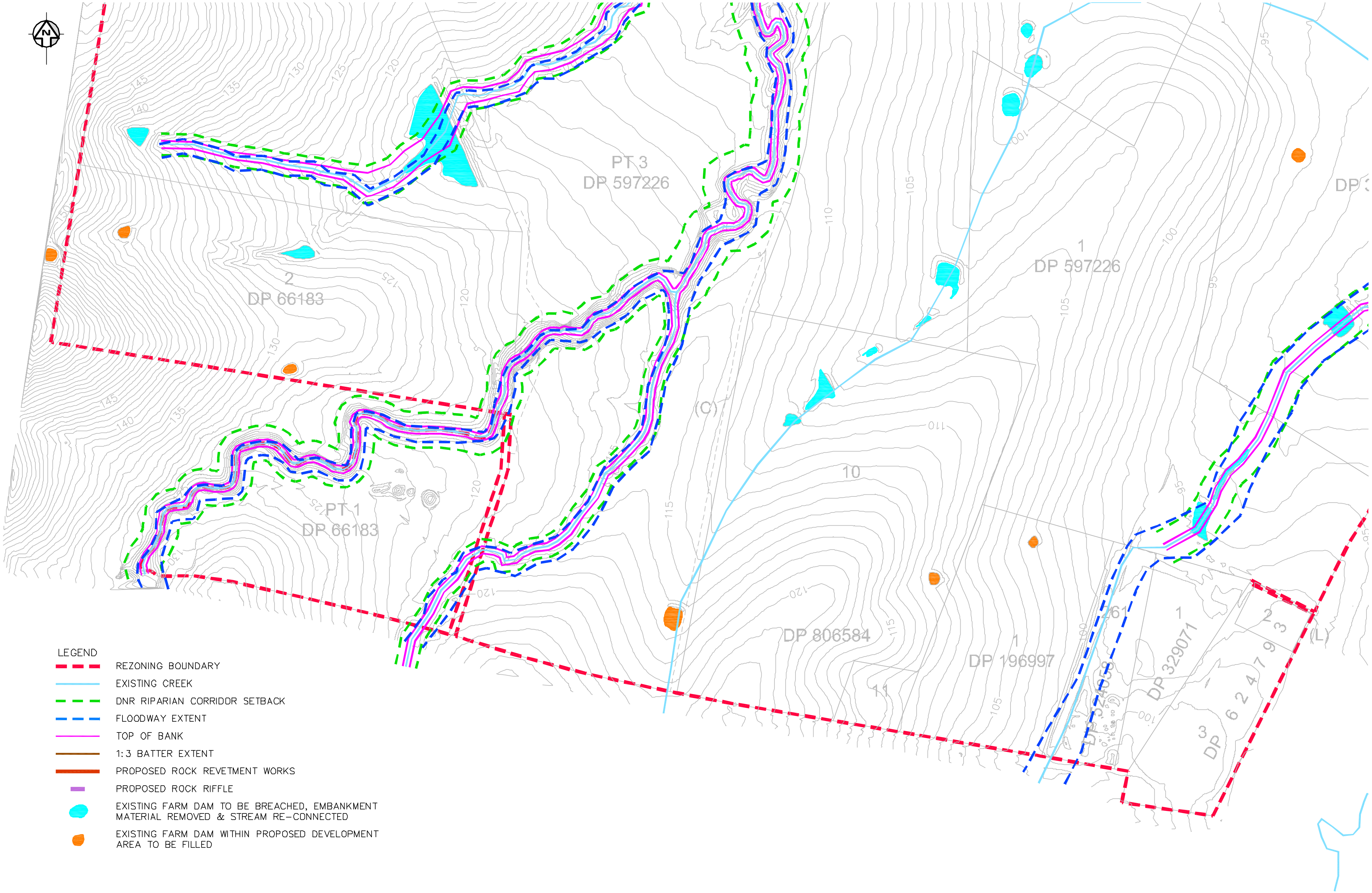
0 200m
1:5000

PROPOSED CREEK REHABILITATION WORKS
SHEET 1

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 30-34 – CREEK REHAB KEY PLAN.dwg 10/08/2007

FIGURE 32



LEGEND
REZONING BOUNDARY
EXISTING CREEK
DNR RIPARIAN CORRIDOR SETBACK
FLOODWAY EXTENT
TOP OF BANK
1:3 BATTER EXTENT
PROPOSED ROCK REVETMENT WORKS
PROPOSED ROCK RIFFLE
EXISTING FARM DAM TO BE BREACHED, EMBANKMENT MATERIAL REMOVED & STREAM RE-CONNECTED
EXISTING FARM DAM WITHIN PROPOSED DEVELOPMENT AREA TO BE FILLED

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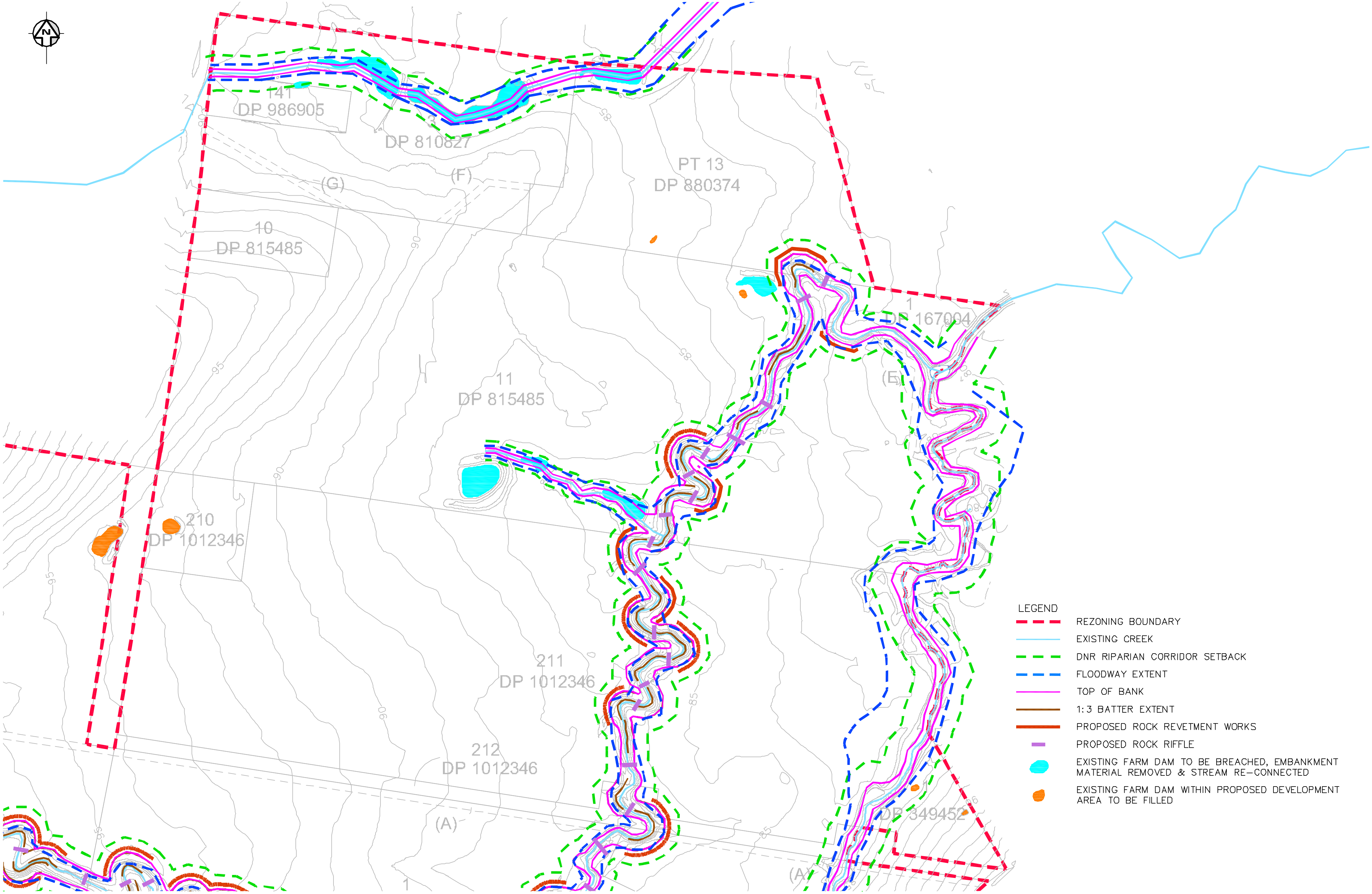
0 200m
1:5000

PROPOSED CREEK REHABILITATION WORKS
SHEET 2

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 30-34 – CREEK REHAB KEY PLAN.dwg 10/08/2007

FIGURE 33



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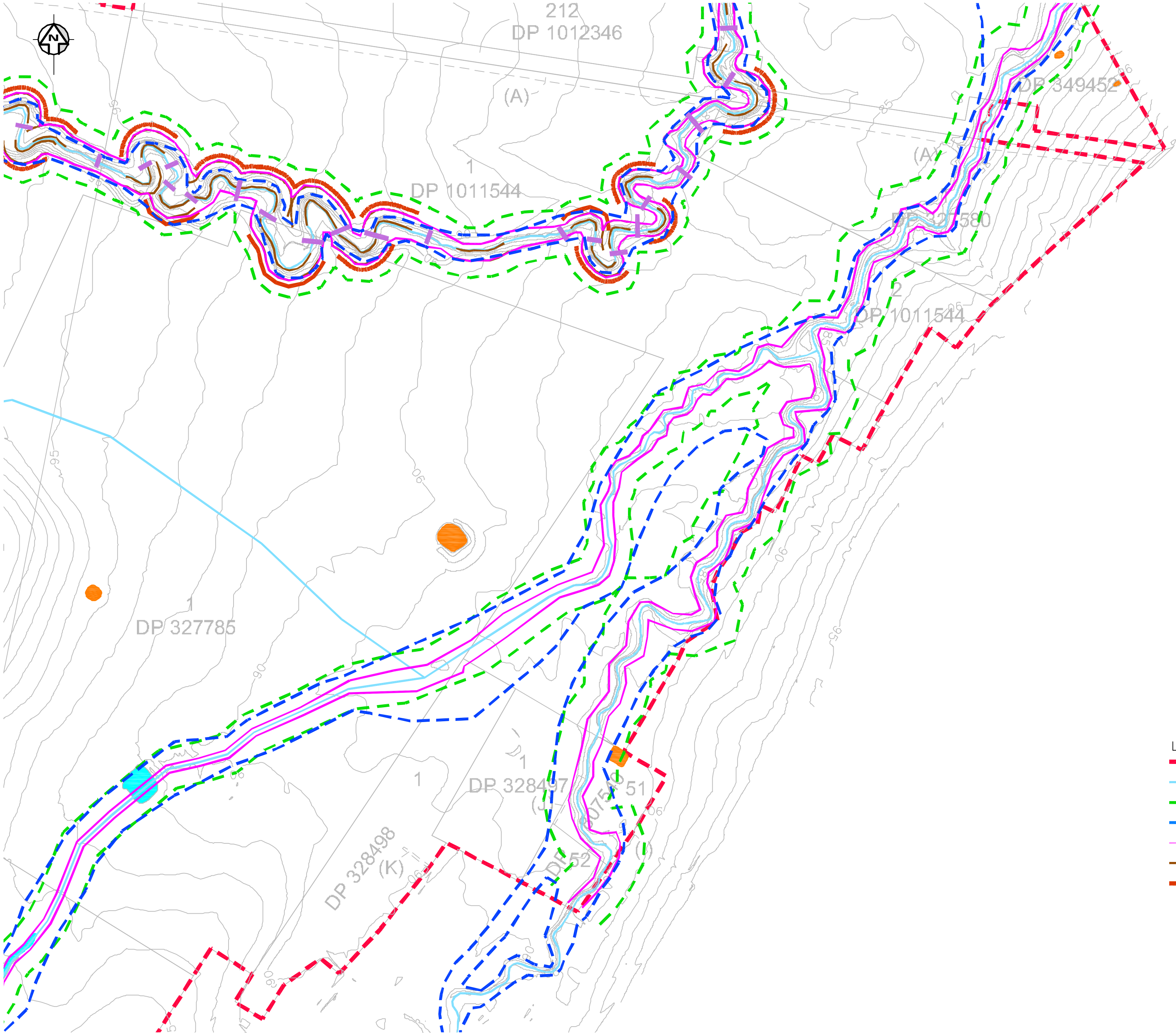
0 200m
1:5000

PROPOSED CREEK REHABILITATION WORKS
SHEET 3

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 30-34 – CREEK REHAB KEY PLAN.dwg 10/08/2007

FIGURE 34



LEGEND

- REZONING BOUNDARY
- EXISTING CREEK
- DNR RIPARIAN CORRIDOR SETBACK
- FLOODWAY EXTENT
- TOP OF BANK
- 1:3 BATTER EXTENT
- PROPOSED ROCK REVETMENT WORKS
- PROPOSED ROCK RIFFLE
- EXISTING FARM DAM TO BE BREACHED, EMBANKMENT MATERIAL REMOVED & STREAM RE-CONNECTED
- EXISTING FARM DAM WITHIN PROPOSED DEVELOPMENT AREA TO BE FILLED

0 200m
1:5000

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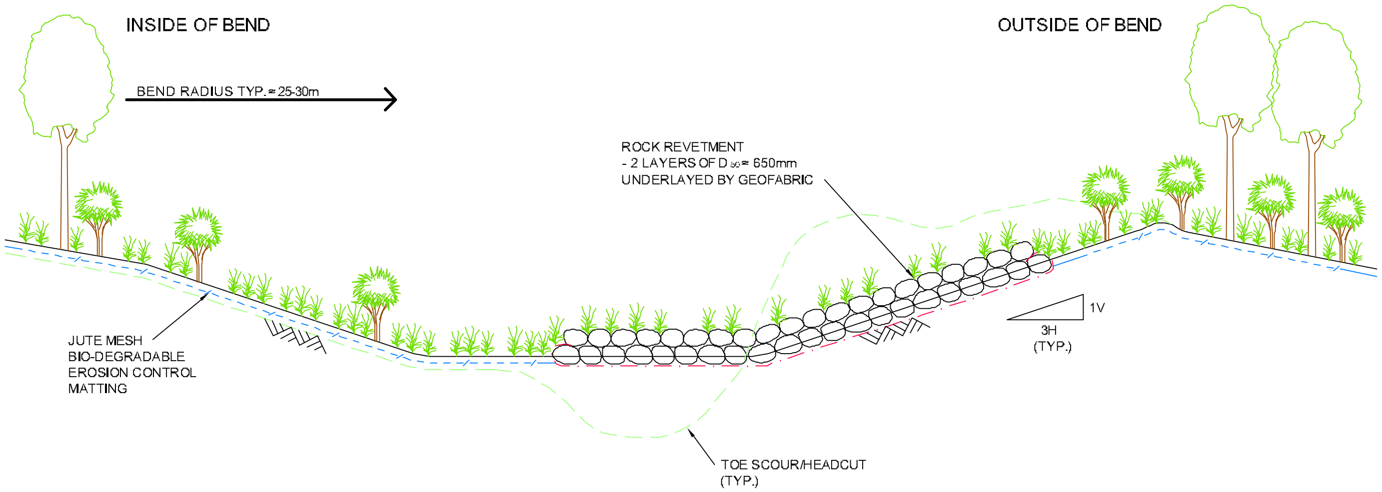
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 30-34 – CREEK REHAB KEY PLAN.dwg 10/08/2007

PROPOSED CREEK REHABILITATION WORKS
SHEET 4



LIMESTONE CREEK - REHABILITATION - TYPICAL DETAIL OF REVETMENT AT OUTSIDE OF CHANNEL BENDS

N.T.S.

LEGEND

- TREE PLANTING
- GROUND COVER/ SEDGE TYPE PLANTING
- SHRUB PLANTING
- EXISTING ERODED & UNDERCUT PROFILE
- FINISHED EARTHWORKS PROFILE
- GEOFABRIC UNDERLAYER
- JUTE MESH BIO-DEGRADABLE EROSION CONTROL MATTING

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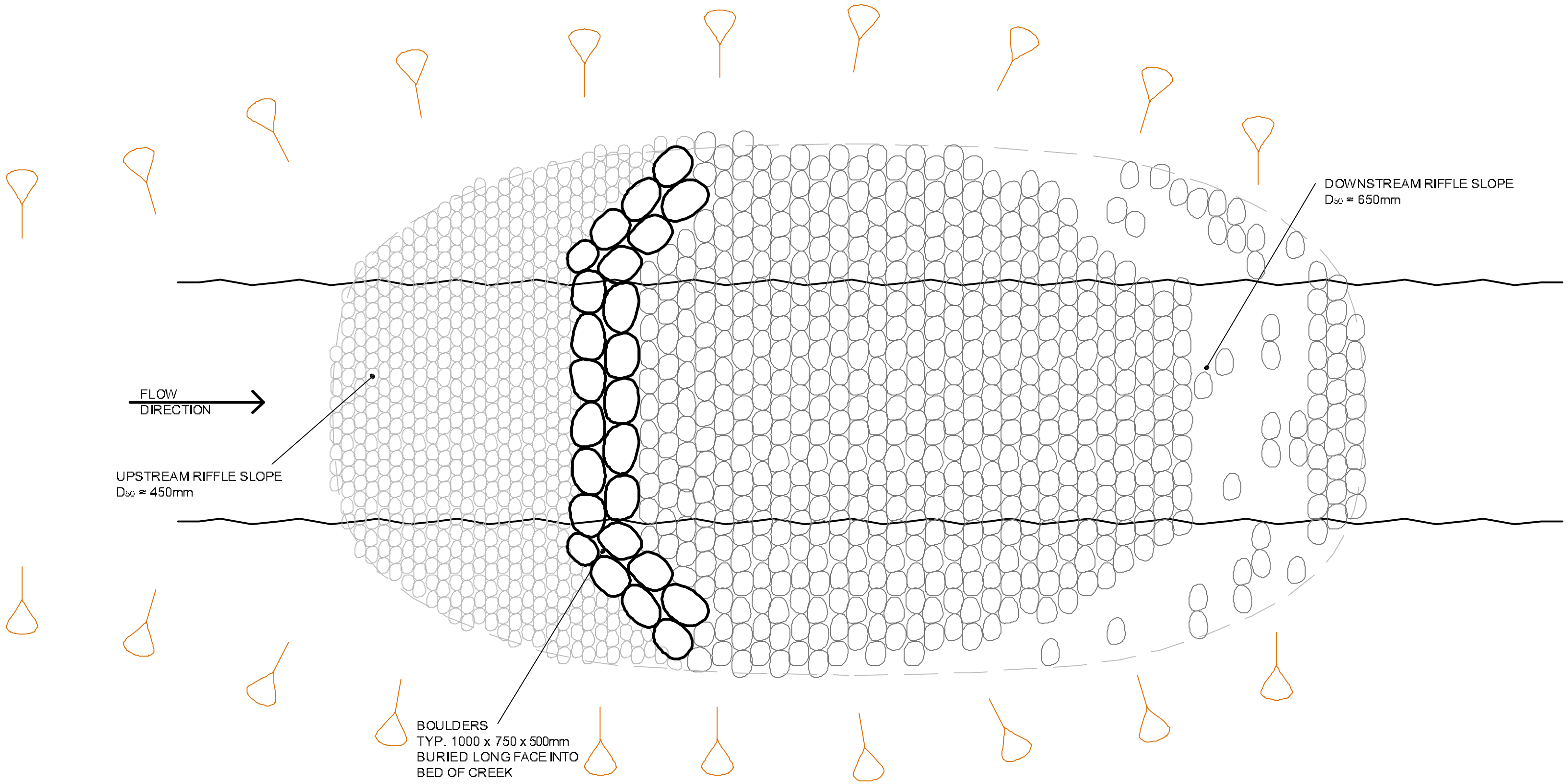
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 35 – CREEK REHAB DETAILS SHEET 1.dwg 10/08/2007

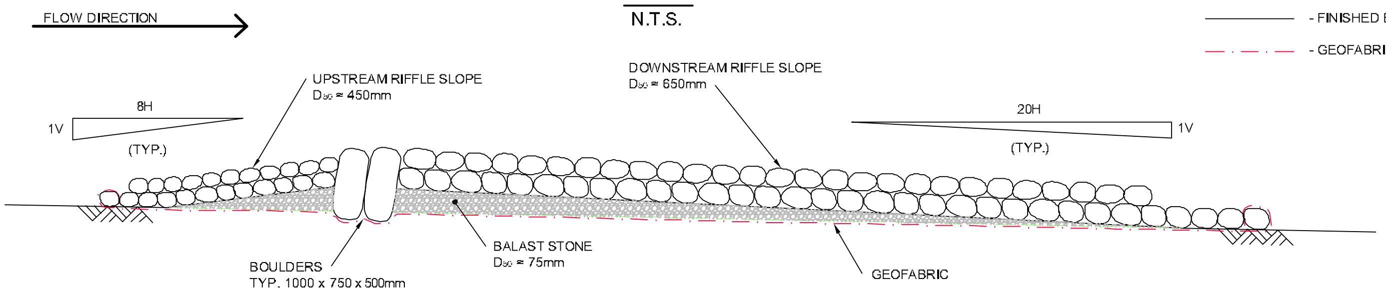
TYPICAL CREEK
REHABILITATION DETAIL
SHEET 1



LIMESTONE CREEK REHABILITATION
ROCK RIFFLE
PLAN
N.T.S.

LEGEND

- EXISTING SURFACE PROFILE
- FINISHED EARTHWORKS PROFILE
- GEOFABRIC UNDERLAYER



TYPICAL SECTION
N.T.S.

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N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 36 – CREEK REHAB DETAILS SHEET 2.dwg 10/08/2007

TYPICAL CREEK
REHABILITATION DETAIL
SHEET 2

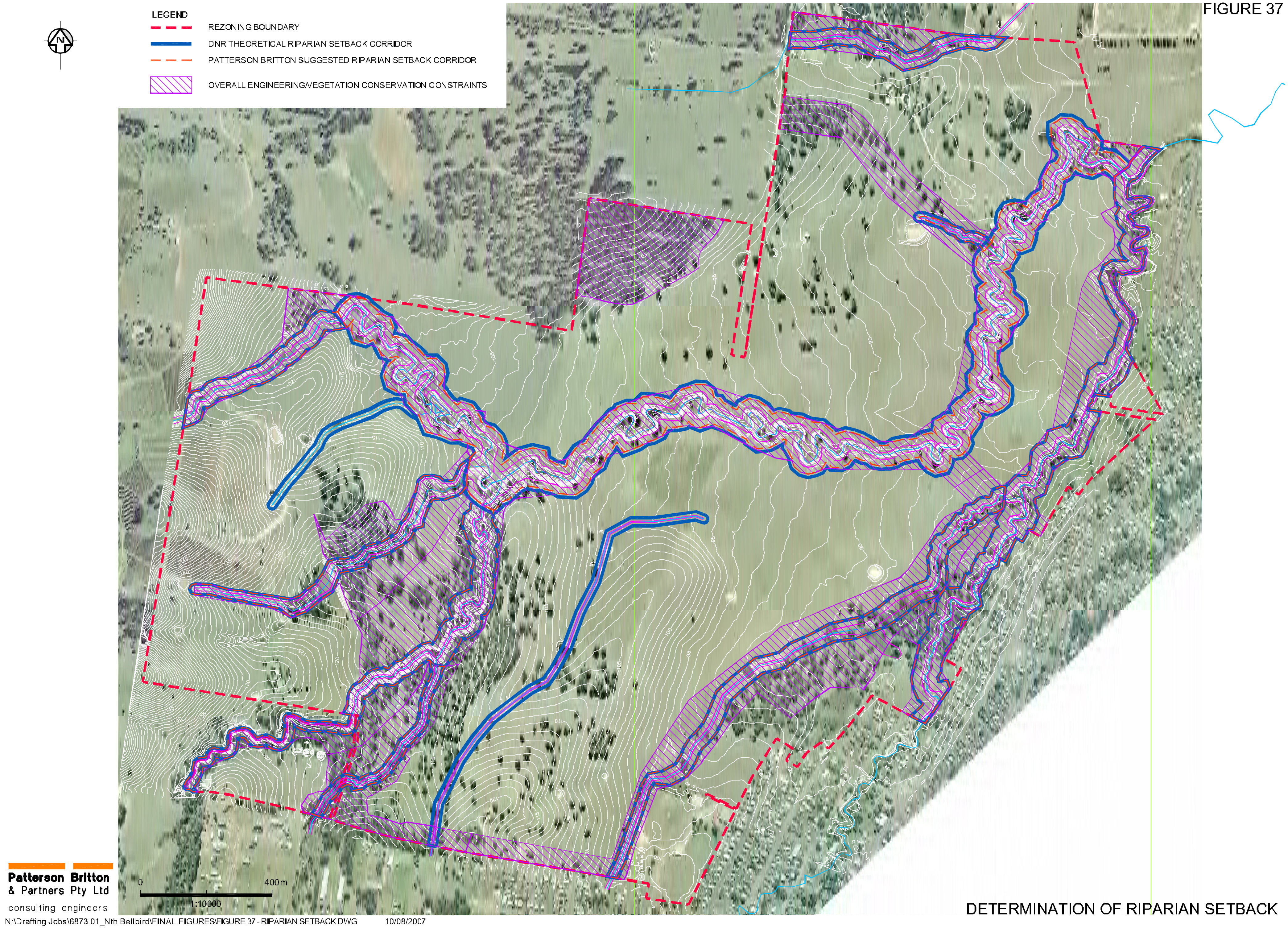
FIGURE 37
LEGEND
REZONING BOUNDARY
DNR THEORETICAL RIPARIAN SETBACK CORRIDOR
PATTERSON BRITTON SUGGESTED RIPARIAN SETBACK CORRIDOR
OVERALL ENGINEERING/VEGETATION CONSERVATION CONSTRAINTS
0
400m
1:10000
Patterson Britton
& Partners Pty Ltd
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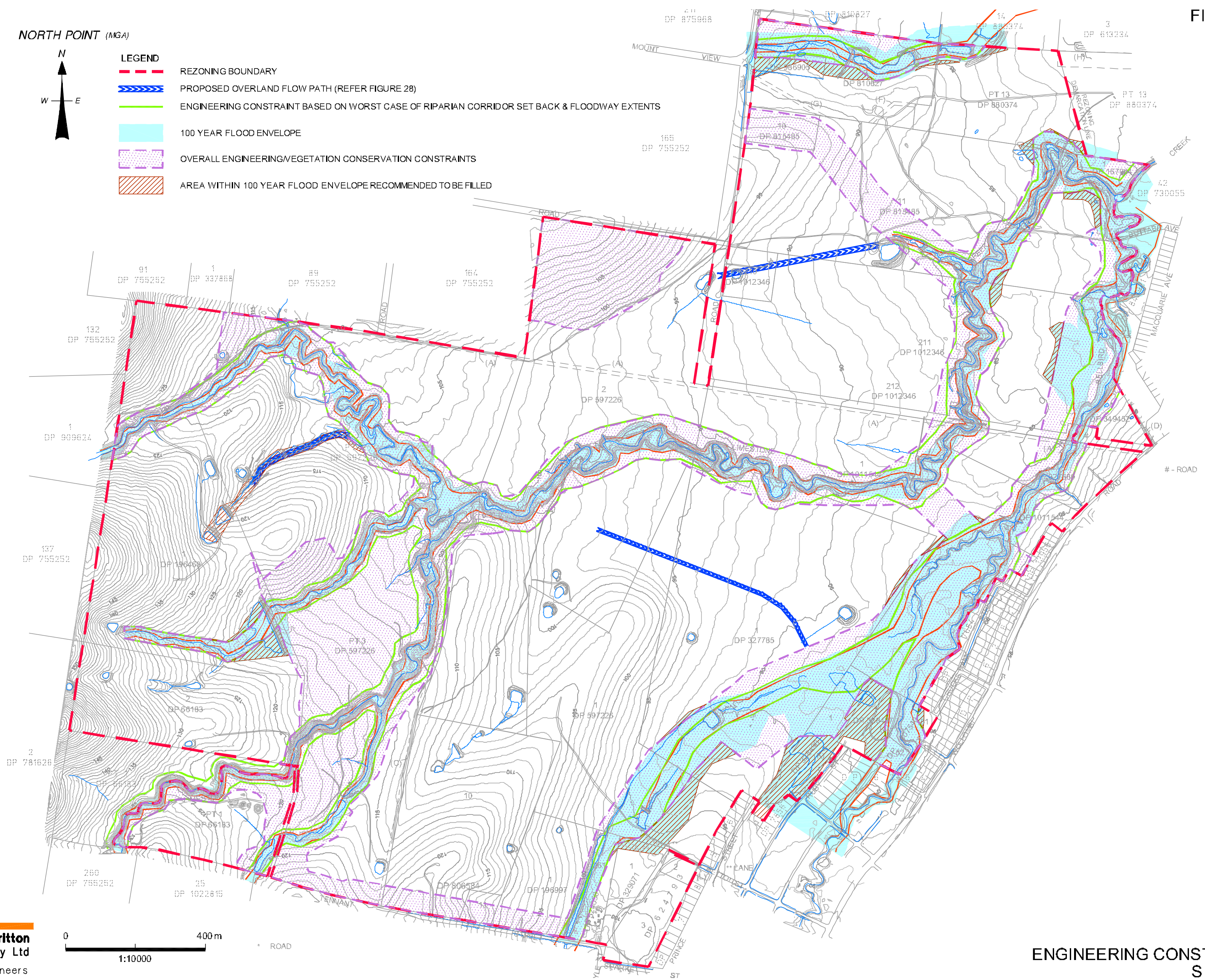
DETERMINATION OF RIPARIAN SETBACK
N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 37 - RIPARIAN SETBACK.DWG 10/08/2007

FIGURE 38



ENGINEERING CONSTRAINTS
SITE PLAN

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N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 38 - ENG CONSTRAINTS SITE PLAN.DWG 10/08/2007

FIGURE 39

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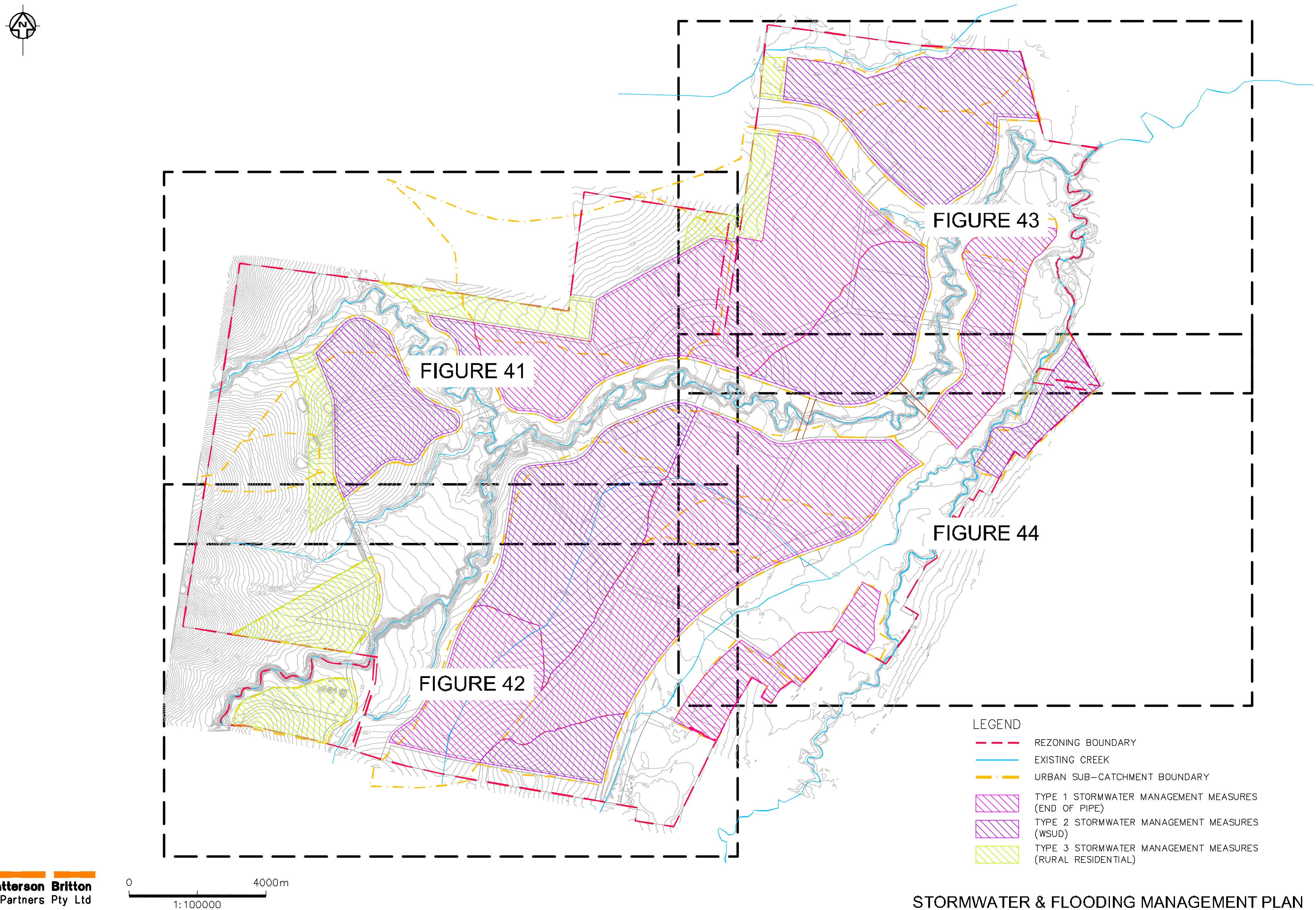
N:\Drafting Jobs\6873.01_Nth Bellbird\PBP REVISED MASTER PLAN & BASINS.DWG 10/08/2007

REVISED DEVELOPMENT MASTER PLAN & STORMWATER MANAGEMENT BASINS



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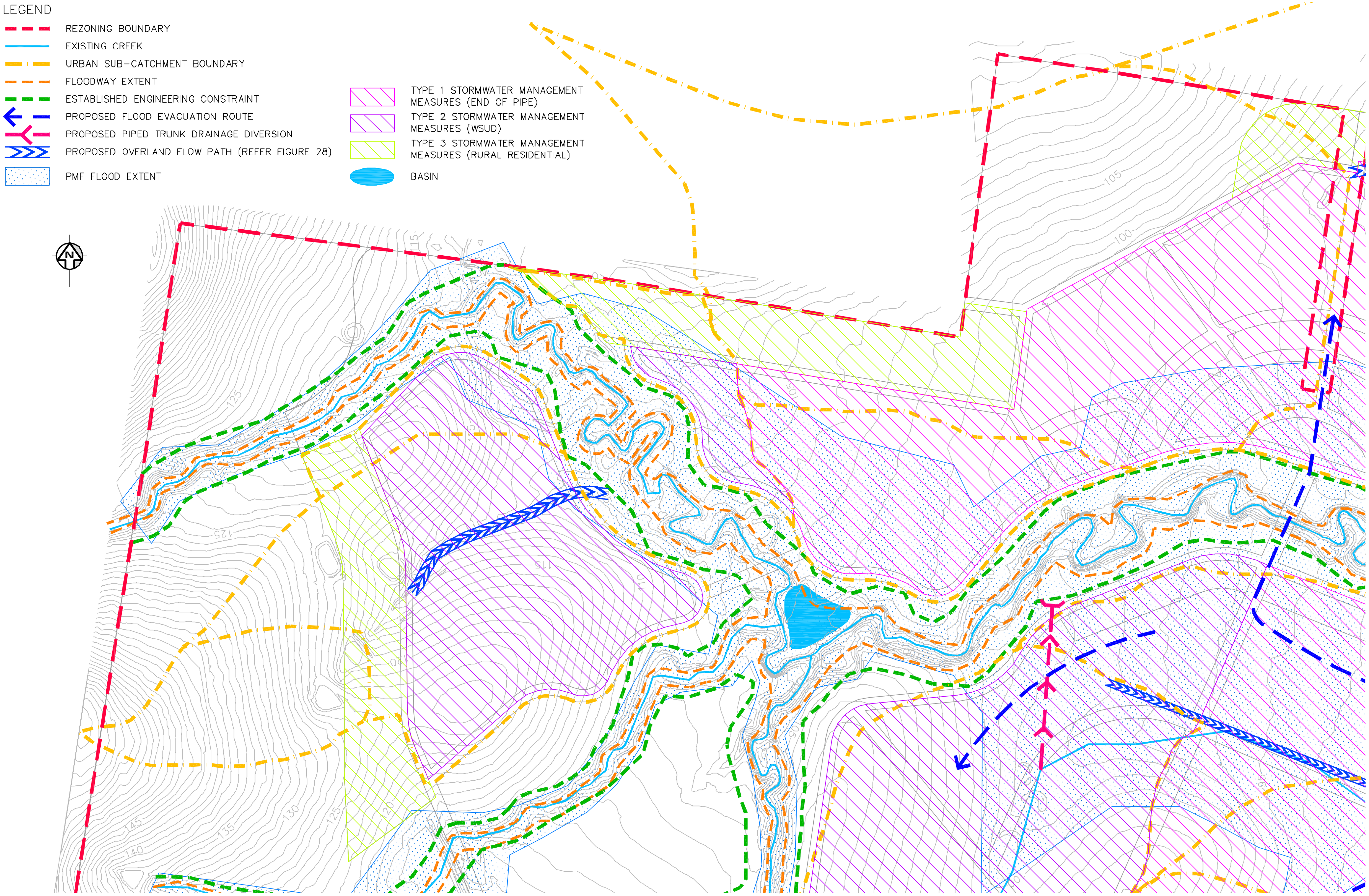
STORMWATER & FLOODING MANAGEMENT PLAN
KEY PLAN

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 40-44 - SWATER & FLOOD MANAG PLAN.dwg 10/08/2007

FIGURE 41



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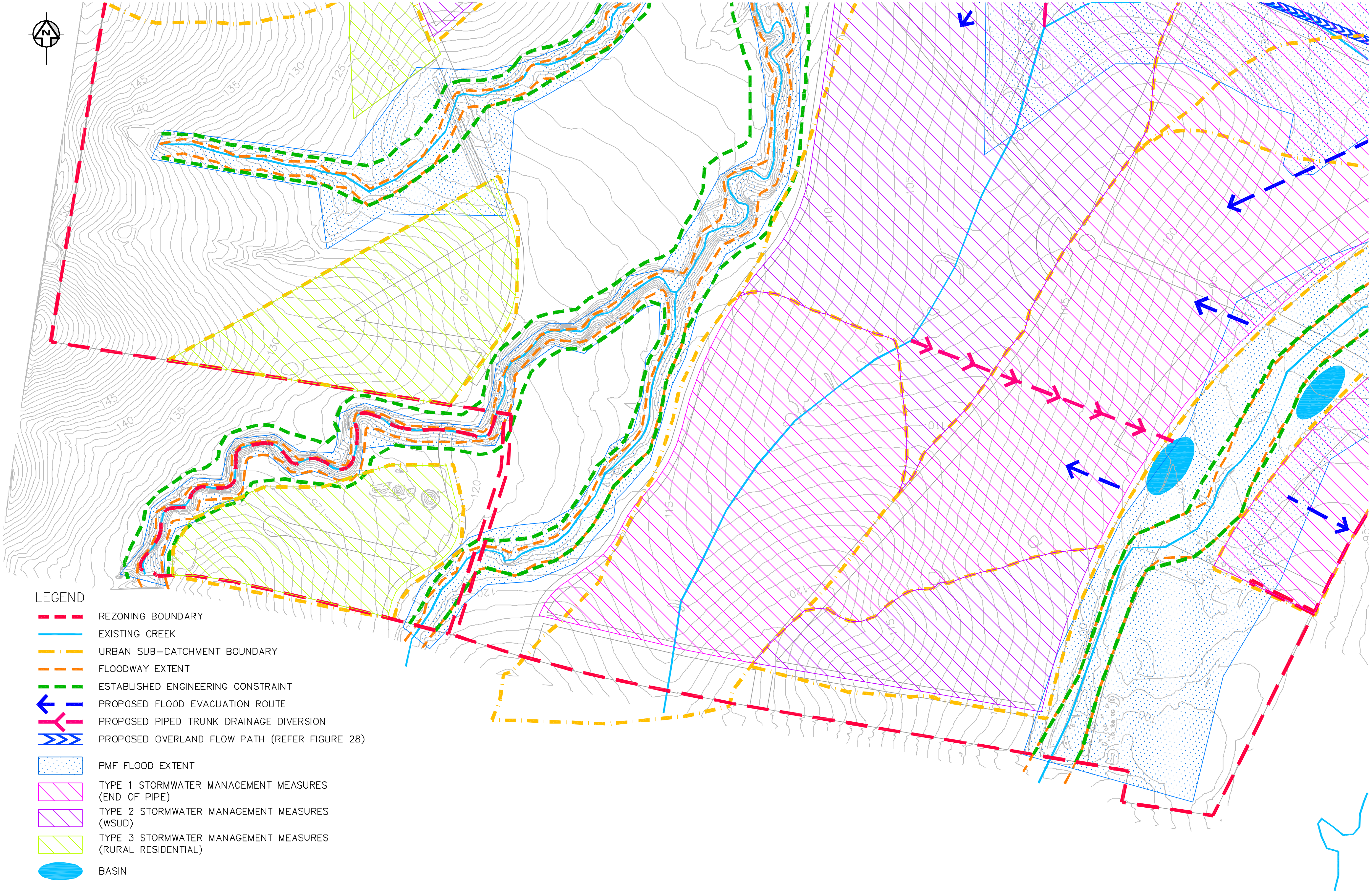
STORMWATER & FLOODING MANAGEMENT PLAN
SHEET 1

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 40-44 - SWATER & FLOOD MANAG PLAN.dwg 10/08/2007



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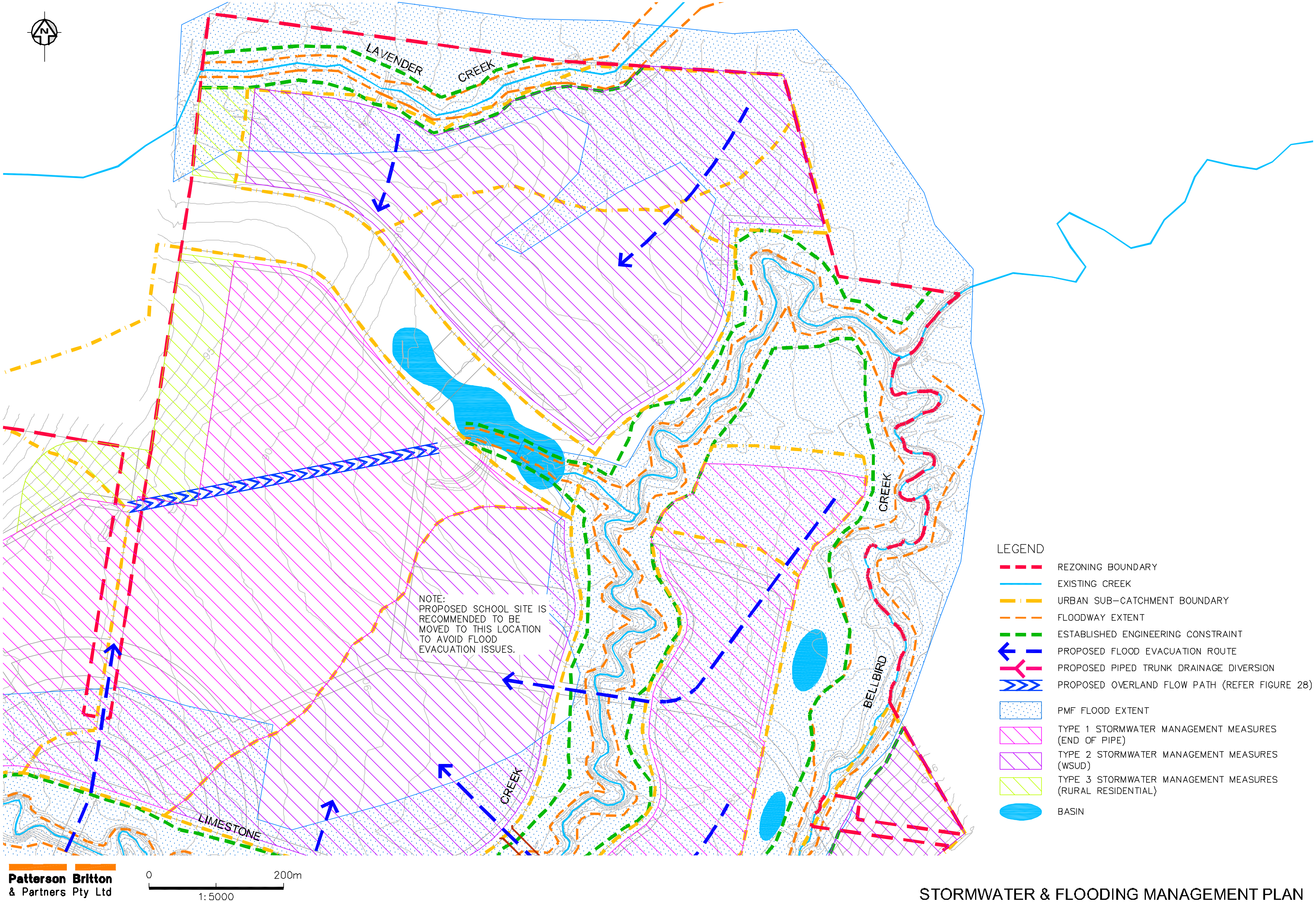
STORMWATER & FLOODING MANAGEMENT PLAN
SHEET 2

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 40-44 – SWATER & FLOOD MANAG PLAN.dwg 10/08/2007



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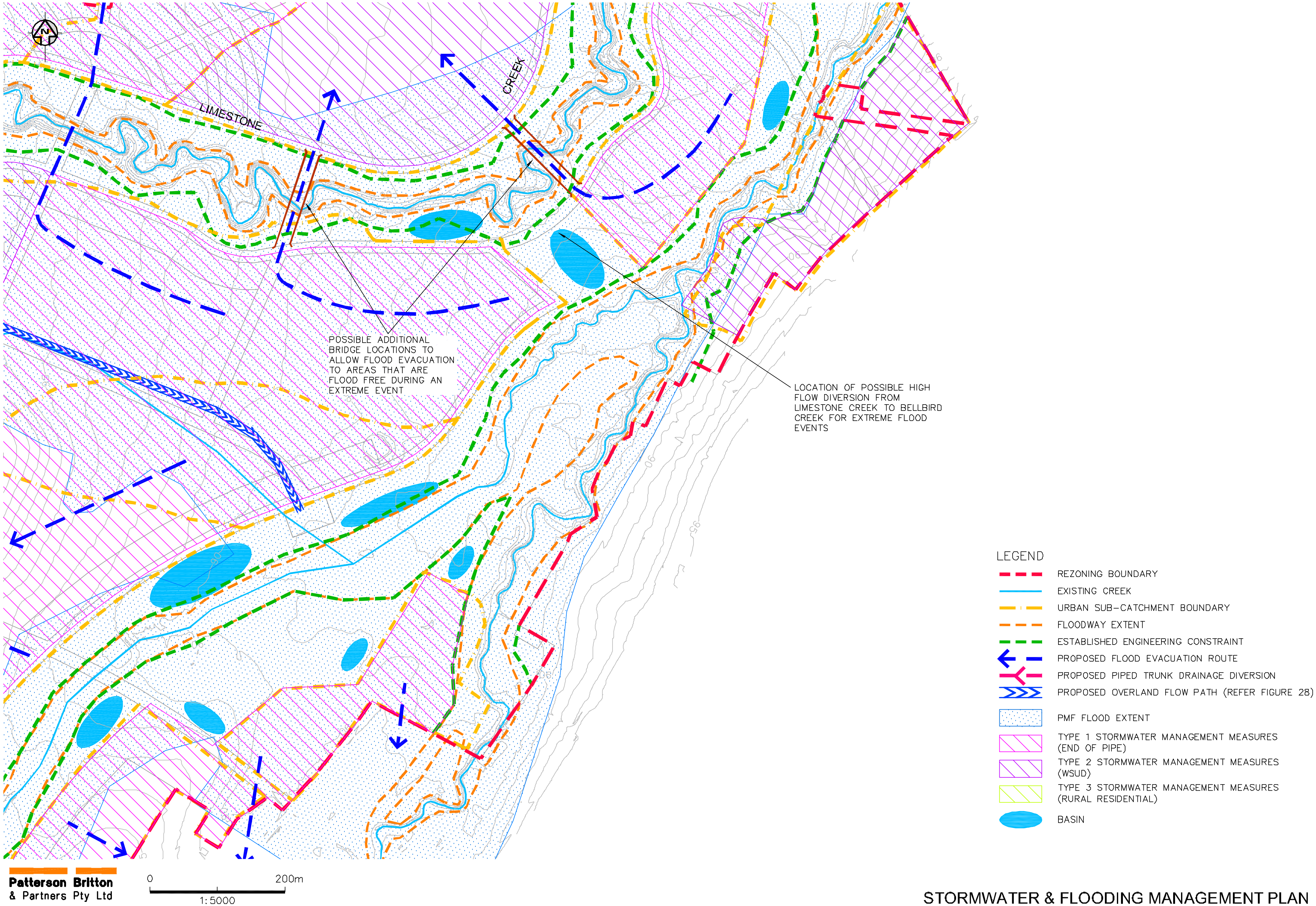
STORMWATER & FLOODING MANAGEMENT PLAN
SHEET 3

N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 40-44 - SWATER & FLOOD MANAG PLAN.dwg 10/08/2007

FIGURE 44



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N:\Drafting Jobs\6873.01_Nth Bellbird\FINAL FIGURES\FIGURE 40-44 – SWATER & FLOOD MANAG PLAN.dwg 10/08/2007

STORMWATER & FLOODING MANAGEMENT PLAN
SHEET 4

APPENDIX A – SUBCATCHMENT PARAMETERS

Developed State RAFTS Subcatchment Parameters

Subcatchment ID	Area (ha)		Slope (%)		Impervious Area (%)		Mannings Roughness		Initial Loss (mm)		Continuing Loss (mm/hr)	
	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
14	41.77	8.69	4.3	4.3	5	100	0.05	0.025	15	1.5	4.5	0
14.01A	2.66	4.94	7	7	0	100	0.035	0.015	15	1.5	2.5	0
14.01	4.02	0	5	0	0	0	0.05	0	15	0	4.5	0
14.02A	8.82	16.38	5	5	0	100	0.035	0.015	15	1.5	2.5	0
14.02B	2	3.71	1	1	0	100	0.035	0.015	15	1.5	2.5	0
14.02	13.9	0	2.6	0	0	0	0.05	0	15	0	4.5	0
10.04A	3.89	7.22	1	1	0	100	0.035	0.015	15	1.5	2.5	0
10.03A	2.31	4.29	0.5	0.5	0	100	0.035	0.015	15	1.5	2.5	0
10.04	5.97	0	1.8	0	0	0	0.05	0	15	0	4.5	0
15	9.15	9.99	5	5	0	100	0.035	0.015	15	1.5	2.5	0
15.01	9.52	17.3	5	5	0	100	0.035	0.015	15	1.5	2.5	0
15.02	8.92	15.33	1	1	0	100	0.035	0.015	15	1.5	2.5	0
10.05	6.1	0.83	1.3	1.3	5	100	0.05	0.025	15	1.5	4.5	0
10	65.74	0	8	0	0	0	0.12	0	15	0	4.5	0
10.01	49.64	0	7	0	0	0	0.12	0	15	0	4.5	0
12	141.57	0	8.6	0	0	0	0.06	0	15	0	4.5	0
13	98.42	0	17	0	0	0	0.12	0	15	0	4.5	0
13.01	126.73	0	9.2	0	0	0	0.12	0	15	0	4.5	0
10.02	1.46	39.64	5.5	5.5	100	0	0.025	0.05	1.5	15	0	4.5
10.03	20.55	38.36	1.9	1.9	100	0	0.025	0.05	1.5	15	0	4.5
11	193.77	0	3.8	0	0	0	0.12	0	15	0	4.5	0
11.01	151.34	0	1.5	0	0	0	0.12	0	15	0	4.5	0
11.02	33.84	9.14	1.6	1.6	5	100	0.12	0.025	15	1.5	4.5	0
11.03	18.92	6.17	3.8	3.8	5	100	0.12	0.025	15	1.5	4.5	0
10.06B	2.52	4.68	5	5	0	100	0.035	0.015	15	1.5	2.5	0
10.06A	4.48	8.32	0.5	0.5	0	100	0.035	0.015	15	1.5	2.5	0
10.06C	2.1	2.1	0.5	0.5	0	100	0.035	0.015	15	1.5	2.5	0
10.06	6.28	27.83	5.6	5.6	100	5	0.025	0.04	1.5	15	0	4.5
20	93.36	0	19	0	0	0	0.12	0	15	0	4.5	0
22	172.36	0	11.4	0	0	0	0.12	0	15	0	4.5	0
20.01	44.45	0	6.6	0	0	0	0.12	0	15	0	4.5	0
21	71.01	0	5.4	0	0	0	0.07	0	15	0	4.5	0
20.02	23.34	0	4.9	0	0	0	0.07	0	15	0	4.5	0
23	48.75	0	24.7	0	0	0	0.12	0	15	0	4.5	0
23.01	86.39	0	5.5	0	0	0	0.07	0	15	0	4.5	0
20.03A	2	3.71	7	7	0	100	0.035	0.015	15	1.5	2.5	0
20.03	18.18	0	5.5	0	0	0	0.07	0	15	0	4.5	0
24	5.25	0.36	10	10	0	100	0.035	0.015	15	1.5	2.5	0
24.01	8.45	10.36	7	7	0	100	0.035	0.015	15	1.5	2.5	0
20.04A	2.31	3.5	1	1	0	100	0.035	0.015	15	1.5	2.5	0
20.04	6.39	0	5.1	0	0	0	0.07	0	15	0	4.5	0
25.00A	5.16	3.44	5	5	0	100	0.035	0.015	15	1.5	2.5	0
25	20.13	0	7.9	0	0	0	0.07	0	15	0	4.5	0
25.01	9.71	0	5.9	0	0	0	0.07	0	15	0	4.5	0
20.05	0.54	0	5.9	0	0	0	0.07	0	15	0	4.5	0
26	77	0	20.5	0	0	0	0.12	0	15	0	4.5	0
26.01	84.76	0	5.5	0	0	0	0.07	0	15	0	4.5	0
26.02	37.26	1.99	6.9	6.9	0	100	0.07	0.025	15	1.5	4.5	0
26.03	2.02	0.06	4.6	4.6	0	100	0.07	0.025	15	1.5	4.5	0
27.00A	3.72	2.48	4	4	0	100	0.035	0.015	15	1.5	2.5	0
27	34.55	0	4.3	0	0	0	0.07	0	15	0	4.5	0
27.01	9.42	0.89	2.7	2.7	10	100	0.07	0.025	15	1.5	4.5	0
26.04	18.82	1.37	3.2	3.2	0	100	0.07	0.025	15	1.5	4.5	0
20.06A	3.71	6.89	1	1	0	100	0.035	0.015	15	1.5	2.5	0
20.06	8.41	0	1.5	0	0	0	0.06	0	15	0	4.5	0
20.07A	7.18	13.33	1.5	1.5	0	100	0.035	0.015	15	1.5	2.5	0
20.07	11.85	0	1.3	0	0	0	0.06	0	15	0	4.5	0
28	29.47	12.23	3.1	3.1	0	100	0.05	0.015	15	1.5	2.5	0
28.01A	15.51	22.29	2	2	0	100	0.035	0.015	15	1.5	2.5	0
28.01	4.36	0	1.4	0	0	0	0.07	0	15	0	2.5	0
20.08	2.3	1.62	1.9	1.9	0	100	0.06	0.025	15	1.5	4.5	0
20.09A	5.04	9.36	1	1	0	100	0.035	0.015	15	1.5	2.5	0
20.09	6.26	0	1.7	0	0	0	0.06	0	15	0	4.5	0
10.07	10.08	28.93	4.6	4.6	100	5	0.025	0.05	1.5	15	0	4.5
10.08	27.27	68	1.5	1.5	100	5	0.025	0.05	1.5	15	0	4.5
7	23.05	0.47	0.5	0.5	5	100	0.07	0.025	15	1.5	4.5	0
2	18.97	0	6.4	0	5	0	0.07	0	15	0	2.5	0
1	42.39	0	7.4	0	5	0	0.07	0	15	0	2.5	0
1.01	25.11	0	5.2	0	5	0	0.07	0	15	0	2.5	0
1.02	16.39	0	2.6	0	5	0	0.07	0	15	0	2.5	0
5	26.58	0	4.8	0	5	0	0.07	0	15	0	2.5	0
1.03	3.69	0	1.2	0	5	0	0.07	0	15	0	2.5	0
3	32.17	0	5.4	0	5	0	0.07	0	15	0	2.5	0
3.01	13.01	0	3.5	0	5	0	0.07	0	15	0	2.5	0
4	20.62	0	4	0	5	0	0.07	0	15	0	2.5	0
3.02	22.65	0	3.7	0	5	0	0.07	0	15	0	2.5	0
3.03	5.81	0	3	0	0	0	0.07	0	15	0	2.5	0
1.04A	4.69	8.71	1.5	1.5	0	100	0.035	0.015	15	1.5	2.5	0
1.04	45.35	0	1.3	0	5	0	0.07	0	15	0	2.5	0
1.05A	0.84	1.56	1.3	1.3	0	100	0.035	0.015	15	1.5	2.5	0
1.05	20.96	0	0.7	0	5	0	0.07	0	15	0	2.5	0
6	3.49	22.75	2.8	2.8	100	5	0.025	0.07	1.5	15	0	2.5
1.06	38.52	0.94	2.7	2.7	5	100	0.07	0.025	15	1.5	2.5	0
1.07	6.05	11.23	1.4	1.4	100	5	0.025	0.05	1.5	15	0	4.5
1.08	4.01	7.44	3.1	3.1	100	5	0.025	0.05	1.5	15	0	4.5
1.09	2.33	7.66	2.9	2.9	100	5	0.025	0.05	1.5	15	0	4.5
1.1	4.79	8.89	3.2	3.2	100	5	0.025	0.05	1.5	15	0	4.5
1.11	2.32	4.3	3.2	3.2	100	5	0.025	0.05	1.5	15	0	4.5
10.09	23.19	12.48	1	1	5	100	0.05	0.025	15	1.5	4.5	0
Outfall	0.00001	0	0.001	0	100	0	0.025	0	15	0	2.5	0

Existing State RAFTS Subcatchment Parameters

Subcatchment ID	Area (ha)		Slope (%)		Impervious Area (%)		Mannings Roughness		Initial Loss (mm)		Continuing Loss (mm/hr)	
	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
10	65.74	0	8	0	0	0	0.12	0	15	0	4.5	0
10.01	49.64	0	7	0	0	0	0.12	0	15	0	4.5	0
12	141.57	0	8.6	0	0	0	0.06	0	15	0	4.5	0
13	98.42	0	17	0	0	0	0.12	0	15	0	4.5	0
13.01	126.73	0	9.2	0	0	0	0.12	0	15	0	4.5	0
10.02	1.46	39.64	5.5	5.5	100	0	0.025	0.05	5	15	0	4.5
10.03	20.55	43.95	1.9	1.9	100	0	0.025	0.05	5	15	0	4.5
11	193.77	0	3.8	0	0	0	0.12	0	15	0	4.5	0
11.01	151.34	0	1.5	0	0	0	0.12	0	15	0	4.5	0
11.02	36.47	9.14	1.6	1.6	5	100	0.12	0.025	15	5	4.5	0
11.03	19.11	5.99	3.8	3.8	5	100	0.12	0.025	15	5	4.5	0
14	41.77	8.69	4.3	4.3	5	100	0.05	0.025	15	5	4.5	0
14.01	11.62	0	5	0	5	0	0.05	0	15	0	4.5	0
14.02	44.8	0	2.6	0	5	0	0.05	0	15	0	4.5	0
10.04	17.07	0	1.8	0	5	0	0.05	0	15	0	4.5	0
15	19.14	0	3	0	0	0	0.07	0	15	0	4.5	0
15.01	26.82	0	3.2	0	0	0	0.07	0	15	0	4.5	0
15.02	24.25	0	1.3	0	0	0	0.07	0	15	0	4.5	0
10.05	6.93	0	1.3	0	5	0	0.05	0	15	0	4.5	0
10.06	6.28	49.63	5.6	5.6	100	5	0.025	0.04	5	15	0	4.5
20	93.36	0	19	0	0	0	0.12	0	15	0	4.5	0
22	172.36	0	11.4	0	0	0	0.12	0	15	0	4.5	0
20.01	44.45	0	6.6	0	0	0	0.12	0	15	0	4.5	0
21	71.01	0	5.4	0	0	0	0.07	0	15	0	4.5	0
20.02	23.34	0	4.9	0	0	0	0.07	0	15	0	4.5	0
23	48.75	0	24.7	0	0	0	0.12	0	15	0	4.5	0
23.01	86.39	0	5.5	0	0	0	0.07	0	15	0	4.5	0
20.03	25.38	0	5.5	0	0	0	0.07	0	15	0	4.5	0
24	5.62	0	9.1	0	0	0	0.07	0	15	0	4.5	0
24.01	13.9	0	7.1	0	0	0	0.07	0	15	0	4.5	0
20.04	11.99	0	5.1	0	0	0	0.07	0	15	0	4.5	0
25	28.73	0	7.9	0	0	0	0.07	0	15	0	4.5	0
25.01	12.87	0	5.9	0	0	0	0.07	0	15	0	4.5	0
20.05	0.54	0	5.9	0	0	0	0.07	0	15	0	4.5	0
26	77	0	20.5	0	0	0	0.12	0	15	0	4.5	0
26.01	84.76	0	5.5	0	0	0	0.07	0	15	0	4.5	0
26.02	39.25	0	6.9	0	0	0	0.07	0	15	0	4.5	0
26.03	2.08	0	4.6	0	0	0	0.07	0	15	0	4.5	0
27	40.75	0	4.3	0	0	0	0.07	0	15	0	4.5	0
27.01	10.31	0	2.7	0	10	0	0.07	0	15	0	4.5	0
26.04	20.19	0	3.2	0	0	0	0.07	0	15	0	4.5	0
20.06	19.01	0	1.5	0	0	0	0.06	0	15	0	4.5	0
20.07	32.35	0	1.3	0	0	0	0.06	0	15	0	4.5	0
28	41.71	0	3.1	0	0	0	0.07	0	15	0	2.5	0
28.01	42.16	0	1.4	0	0	0	0.07	0	15	0	2.5	0
20.08	3.92	0	1.9	0	0	0	0.06	0	15	0	4.5	0
20.09	18.16	0	1.7	0	0	0	0.06	0	15	0	4.5	0
10.07	10.08	28.93	4.6	4.6	100	5	0.025	0.05	5	15	0	4.5
10.08	27.27	68	1.5	1.5	100	5	0.025	0.05	5	15	0	4.5
7	23.05	0.47	0.5	0.5	5	100	0.07	0.025	15	5	4.5	0
2	18.97	0	6.4	0	5	0	0.07	0	15	0	2.5	0
1	42.39	0	7.4	0	5	0	0.07	0	15	0	2.5	0
1.01	25.11	0	5.2	0	5	0	0.07	0	15	0	2.5	0
1.02	16.39	0	2.6	0	5	0	0.07	0	15	0	2.5	0
5	26.58	0	4.8	0	5	0	0.07	0	15	0	2.5	0
1.03	3.69	0	1.2	0	5	0	0.07	0	15	0	2.5	0
3	32.17	0	5.4	0	5	0	0.07	0	15	0	2.5	0
3.01	13.01	0	3.5	0	5	0	0.07	0	15	0	2.5	0
4	20.62	0	4	0	5	0	0.07	0	15	0	2.5	0
3.02	22.65	0	3.7	0	5	0	0.07	0	15	0	2.5	0
3.03	9.31	0	3	0	5	0	0.07	0	15	0	2.5	0
1.04	57.05	0	1.3	0	5	0	0.07	0	15	0	2.5	0
1.05	23.36	0	0.7	0	5	0	0.07	0	15	0	2.5	0
6	3.49	22.75	2.8	2.8	100	5	0.025	0.07	5	15	0	2.5
1.06	38.52	0.94	2.7	2.7	5	100	0.07	0.025	15	5	2.5	0
1.07	6.05	11.23	1.4	1.4	100	5	0.025	0.05	5	15	0	4.5
1.08	4.01	7.44	3.1	3.1	100	5	0.025	0.05	5	15	0	4.5
1.09	2.33	7.66	2.9	2.9	100	5	0.025	0.05	5	15	0	4.5
1.1	4.79	8.89	3.2	3.2	100	5	0.025	0.05	5	15	0	4.5
1.11	2.32	4.3	3.2	3.2	100	5	0.025	0.05	5	15	0	4.5
10.09	23.19	12.48	1	1	5	100	0.05	0.025	15	5	4.5	0
Outfall	0.00001	0	0.001	0	100	0	0.025	0	15	0	2.5	0

Developed State RAFTS Hydrograph Lagtimes

RAFTS Link	Hydrograph Lag [mins]
10.00 - 10.01 ()	8
10.01 - 10.02 (212)	4
10.02 - 10.03 (213)	22
10.03 - 11.02 (214)	6
10.04 - 10.05 (215)	3
10.05 - 10.06 (216)	11
10.06 - 10.07 (217)	8
10.07 - 10.08 (218)	12
10.08 - 10.09 (219)	6
11.00 - 11.01 (224)	23
11.03 - 10.06 (226)	13
12.00 - 13.01 (230)	16
13.01 - 10.02 (231)	4
13.00 - 13.01 (232)	19
20.00 - 20.01 (240)	10.2
20.01 - 20.02 (241)	6.8
20.02 - 20.03 (242)	5
20.03 - 20.04 (243)	3
20.04 - 20.05 (244)	1.5
20.05 - 20.06 (245)	10
21.00 - 20.02 (246)	6.8
22.00 - 20.01 (248)	10.2
23.00 - 23.01 (251)	16
23.01 - 20.03 (252)	9.6
24.01 - 20.04 (254)	3
26.00 - 26.01 (259)	10
26.01 - 26.02 (260)	11
26.02 - 26.03 (261)	2
26.03 - 26.04 (262)	3
27.01 - 26.04 (264)	6
14.02 - 10.04 (268)	3.5
7.00 - 1.09 (272)	10.1
1.08 - 1.09 (274)	5
1.09 - 1.10 (276)	7
1.10 - 1.11 (278)	7
1.07 - 1.08 (280)	8
1.06 - 1.07 (282)	20
2.00 - 1.01 (285)	12
1.01 - 1.02 (287)	30
1.02 - 1.03 (289)	15
1.03 - 1.04 (291)	10
1.05 - 1.06 (292)	10
1.00 - 1.01 (294)	12
5.00 - 1.03 (296)	15
3.00 - 3.01 (299)	10
3.01 - 3.02 (301)	12
3.02 - 3.03 (302)	6
4.00 - 3.02 (304)	12
6.00 - 1.06 (306)	10
1.04 - 1.05 (308)	10
10.09 - Outfall (320)	0
1.11 - 10.09 (321)	6
3.03 - 1.04 (link4)	4
24.00 - 24.01 (link7)	2
26.04 - 20.06 (link8)	7
25.00 - 25.01 (link9)	4
25.01 - 20.05 (link10)	3
27.00 - 27.01 (link11)	0
20.06 - 20.07 (link12)	18
20.07 - 20.08 (link13)	3
20.08 - 20.09 (link14)	5
20.09 - 10.07 (link15)	6
28.00 - 28.01A (link16)	7
28.01 - 20.08 (link17)	4
15.00 - 15.01 (link1)	4
15.01 - 15.02 (link5)	4
14.00 - 14.01 (link19)	3
14.01 - 14.02 (link20)	5
11.01 - 11.02 (link23)	11
11.02 - 11.03 (link24)	5
15.02 - 10.05 (link3)	2.5
28.01A - 28.01 (link2)	0
20.07A - 20.07 (link18)	0
20.09A - 20.09 (link21)	0
1.04A - 1.04 (link22)	0
1.05A - 1.05 (link25)	0
10.06B - 10.06 (link26)	5
10.06A - 10.06 (link27)	5
10.06C - 10.06 (link28)	0
20.04A - 20.04 (link29)	5
20.06A - 20.06 (link30)	0
20.03A - 20.03 (link31)	0
25.00A - 25.00 (link32)	0
27.00A - 27.00 (link33)	0
14.01A - 14.01 (link34)	0
14.02A - 14.02 (link35)	0
14.02B - 14.02 (link36)	0
10.04A - 10.04 (link37)	0
10.03A - 10.04 (link38)	5

IFD ANALYSIS BASED ON AUSTRALIAN RAINFALL & RUNOFF (1987)

Site name: **Cessnock**

Site latitude = 32.33 degrees S
longitude = 151.33 degrees E
skewness = 0.06

2-year ARI
1 hour intensity = 27.50 mm/hr
12 hour intensity = 6.70 mm/hr
72 hour intensity = 1.75 mm/hr

50-year ARI
1 hour intensity = 50.00 mm/hr
12 hour intensity = 12.00 mm/hr
72 hour intensity = 3.50 mm/hr

IFD Table for Various ARIs and Duration

Duration min	1 yr mm/h	2 yr mm/h	5 yr mm/h	10 yr mm/h	20 yr mm/h	50 yr mm/h	100 yr mm/h
5	70.38	90.87	117.32	132.98	153.72	181.18	202.3
6	65.91	85.04	109.6	124.12	143.37	168.83	188.41
10	53.81	69.29	88.82	100.3	115.58	135.74	151.21
12	49.7	63.95	81.81	92.28	106.24	124.64	138.75
15	44.88	57.69	73.6	82.91	95.34	111.7	124.23
18	41.14	52.83	67.24	75.65	86.9	101.7	113.02
20	39.05	50.13	63.72	71.63	82.24	96.17	106.83
24	35.61	45.66	57.9	65.01	74.55	87.08	96.64
30	31.67	40.56	51.27	57.47	65.82	76.76	85.11
45	25.33	32.38	40.68	45.46	51.93	60.38	66.82
1 (hr)	21.48	27.4	34.29	38.22	43.58	50.56	55.87
1.5	17.17	21.9	27.37	30.5	34.75	40.3	44.52
2	14.6	18.61	23.25	25.89	29.5	34.2	37.76
3	11.58	14.76	18.42	20.51	23.35	27.06	29.87
4.5	9.18	11.7	14.58	16.22	18.47	21.39	23.6
6	7.79	9.92	12.36	13.74	15.64	18.1	19.97
9	6.18	7.87	9.79	10.88	12.38	14.32	15.8
12	5.25	6.68	8.3	9.23	10.49	12.13	13.38
18	3.93	5.02	6.3	7.04	8.04	9.34	10.33
24	3.19	4.09	5.17	5.79	6.64	7.74	8.58
30	2.71	3.48	4.42	4.97	5.7	6.67	7.41
36	2.36	3.04	3.88	4.37	5.03	5.89	6.56
48	1.89	2.43	3.13	3.54	4.09	4.81	5.37
72	1.35	1.74	2.27	2.58	3	3.54	3.97

APPENDIX B – HYDROLOGY RESULTS

Summary of Rafts Results

Existing State Results

Catchment name	10.07	
Storm ARI	Duration (min)	Peak Flow (m3/s)
2 yr	60 min	12.050
2 yr	90 min	17.738
2 yr	120 min	22.642
2 yr	180 min	27.843
2 yr	270 min	31.732
2 yr	360 min	36.382
2 yr	**540 min**	**49.443**
2 yr	720 min	39.875
2 yr	1080 min	30.648
5 yr	60 min	25.135
5 yr	90 min	33.901
5 yr	120 min	41.245
5 yr	180 min	48.097
5 yr	270 min	52.231
5 yr	360 min	58.456
5 yr	**540 min**	**72.748**
5 yr	720 min	57.364
5 yr	1080 min	47.3178
20 yr	60 min	44.7389
20 yr	90 min	57.2993
20 yr	120 min	66.9211
20 yr	180 min	75.525
20 yr	270 min	79.169
20 yr	360 min	89.054
20 yr	**540 min**	**105.574**
20 yr	720 min	85.176
20 yr	1080 min	69.103
100 yr	60 min	74.402
100 yr	90 min	92.067
100 yr	120 min	105.592
100 yr	180 min	114.382
100 yr	270 min	115.958
100 yr	360 min	127.000
100 yr	**540 min**	**143.105**
100 yr	720 min	119.545
100 yr	1080 min	93.641

Developed State Results

Catchment name	10.07	
Storm ARI	Duration (min)	Peak Flow (m3/s)
2 yr	60 min	29.3101
2 yr	90 min	28.6714
2 yr	120 min	30.2267
2 yr	180 min	29.2347
2 yr	270 min	33.2793
2 yr	360 min	38.1193
2 yr	**540 min**	**50.2519**
2 yr	720 min	41.5468
2 yr	1080 min	32.8564
5 yr	60 min	38.5824
5 yr	90 min	38.0908
5 yr	120 min	41.1871
5 yr	180 min	48.7253
5 yr	270 min	53.0993
5 yr	360 min	59.4193
5 yr	**540 min**	**72.4195**
5 yr	720 min	58.8022
5 yr	1080 min	48.8886
20 yr	60 min	51.239
20 yr	90 min	54.4605
20 yr	120 min	65.6598
20 yr	180 min	75.1586
20 yr	270 min	79.2295
20 yr	360 min	88.577
20 yr	**540 min**	**103.62**
20 yr	720 min	81.1321
20 yr	1080 min	70.1924
100 yr	60 min	69.0289
100 yr	90 min	85.7685
100 yr	120 min	101.556
100 yr	180 min	112.713
100 yr	270 min	115.185
100 yr	360 min	125.32
100 yr	**540 min**	**139.771**
100 yr	720 min	97.1291
100 yr	1080 min	82.3065

APPENDIX C – PMP HYDROLOGY RESULTS

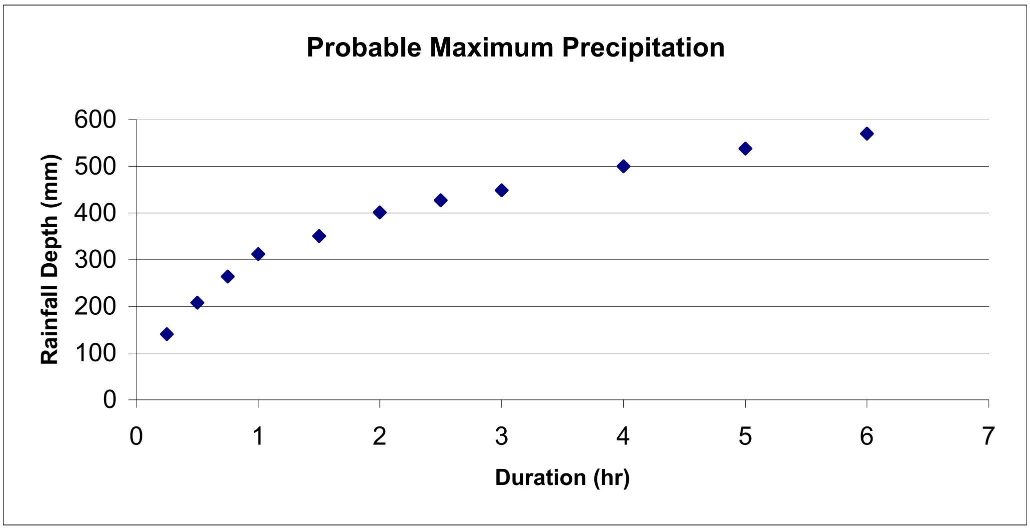
Bellbird PMP Calculation
6873
KEM 11/5/07

Patterson Britton & Partners Pty Ltd
consulting engineers

O:\6873-01_ North Bellbird - Floodplain Management Plan & DCP (BP)\PMP\[pmp data.xls]Temporal Distribution
NB. Data entry required in orange cells

			Reference
Mean Elevation	150	m	
EAF	1	[-]	*§4.3*
MAF	0.73	[-]	*Figure 3*
S	1	[-]	
R	0	[-]	
Area of catchment	29.7	km^2	
Maximum Duration	6	hr	*Figure 2*

Duration (hr)	D_S (mm)	D_R (mm)	PMP (mm)	Adopted PMP (mm)
0.25	193	193	140.89	140
0.5	285	285	208.05	210
0.75	362	362	264.26	260
1	427	427	311.71	310
1.5	480	550	350.4	350
2	550	640	401.5	400
2.5	585	710	427.05	430
3	615	770	448.95	450
4	685	880	500.05	500
5	737	965	538.01	540
6	781	1030	570.13	570



6873 - North Bellbird

PMP Estimation

O:\6873-01_ North Bellbird - Floodplain Management Plan & DCP (BP)\PMP\[pmp data.xls]Temporal Distribution
KEM 11/5/07

Ellipse
A

	Duration (hr)	0.25		0.5		0.75		1		1.5		2		2.5		3		4		5		6	
	PMP (mm)	169		245		310		360		411		458		488		515		563		607		642	
% of time	% of PMP	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)
0	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	4	0.75	6.8	1.5	9.8	2.25	12.4	3	14.4	4.5	16.4	6	18.3	7.5	19.5	9	20.6	12	22.5	15	24.3	18	25.7
10	10	1.5	16.9	3	24.5	4.5	31.0	6	36.0	9	41.1	12	45.8	15	48.8	18	51.5	24	56.3	30	60.7	36	64.2
15	18	2.25	30.5	4.5	44.2	6.75	55.8	9	64.8	13.5	74.0	18	82.5	22.5	87.9	27	92.6	36	101.3	45	109.3	54	115.5
20	25	3	42.3	6	61.3	9	77.6	12	90.0	18	102.7	24	114.6	30	122.1	36	128.7	48	140.7	60	151.8	72	160.4
25	32	3.75	54.2	7.5	78.5	11.25	99.3	15	115.2	22.5	131.5	30	146.7	37.5	156.3	45	164.7	60	180.1	75	194.4	90	205.3
30	39	4.5	66.1	9	95.7	13.5	121.0	18	140.4	27	160.3	36	178.8	45	190.5	54	200.7	72	219.5	90	236.9	108	250.3
35	46	5.25	77.9	10.5	112.8	15.75	142.7	21	165.5	31.5	189.1	42	210.9	52.5	224.7	63	236.7	84	258.9	105	279.4	126	295.2
40	52	6	88.1	12	127.5	18	161.3	24	187.1	36	213.7	48	238.4	60	254.0	72	267.6	96	292.7	120	315.8	144	333.7
45	59	6.75	99.9	13.5	144.7	20.25	183.0	27	212.3	40.5	242.5	54	270.5	67.5	288.1	81	303.6	108	332.1	135	358.3	162	378.6
50	64	7.5	108.4	15	157.0	22.5	198.6	30	230.3	45	263.0	60	293.4	75	312.6	90	329.4	120	360.2	150	388.7	180	410.7
55	70	8.25	118.6	16.5	171.7	24.75	217.2	33	251.9	49.5	287.7	66	320.9	82.5	341.9	99	360.3	132	394.0	165	425.2	198	449.2
60	75	9	127.0	18	184.0	27	232.7	36	269.9	54	308.2	72	343.8	90	366.3	108	386.0	144	422.1	180	455.5	216	481.3
65	80	9.75	135.5	19.5	196.2	29.25	248.2	39	287.9	58.5	328.8	78	366.8	97.5	390.7	117	411.7	156	450.3	195	485.9	234	513.3
70	85	10.5	144.0	21	208.5	31.5	263.7	42	305.9	63	349.3	84	389.7	105	415.1	126	437.5	168	478.4	210	516.3	252	545.4
75	89	11.25	150.7	22.5	218.3	33.75	276.1	45	320.3	67.5	365.8	90	408.0	112.5	434.6	135	458.0	180	500.9	225	540.6	270	571.1
80	92	12	155.8	24	225.7	36	285.4	48	331.1	72	378.1	96	421.8	120	449.3	144	473.5	192	517.8	240	558.8	288	590.3
85	95	12.75	160.9	25.5	233.0	38.25	294.7	51	341.9	76.5	390.4	102	435.5	127.5	464.0	153	488.9	204	534.7	255	577.0	306	609.6
90	97	13.5	164.3	27	237.9	40.5	300.9	54	349.1	81	398.7	108	444.7	135	473.7	162	499.2	216	545.9	270	589.1	324	622.4
95	99	14.25	167.7	28.5	242.8	42.75	307.1	57	356.3	85.5	406.9	114	453.9	142.5	483.5	171	509.5	228	557.2	285	601.3	342	635.3
100	100	15	169.4	30	245.3	45	310.3	60	359.9	90	411.0	120	458.4	150	488.4	180	514.7	240	562.8	300	607.4	360	641.7

% of time	% of PMP	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)
0	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	4	0.75	6.8	1.5	9.8	2.25	12.4	3	14.4	4.5	16.4	6	18.3	7.5	19.5	9	20.6	12	22.5	15	24.3	18	25.7
10	6	1.5	10.2	3	14.7	4.5	18.6	6	21.6	9	24.7	12	27.5	15	29.3	18	30.9	24	33.8	30	36.4	36	38.5
15	8	2.25	13.5	4.5	19.6	6.75	24.8	9	28.8	13.5	32.9	18	36.7	22.5	39.1	27	41.2	36	45.0	45	48.6	54	51.3
20	7	3	11.9	6	17.2	9	21.7	12	25.2	18	28.8	24	32.1	30	34.2	36	36.0	48	39.4	60	42.5	72	44.9
25	7	3.75	11.9	7.5	17.2	11.25	21.7	15	25.2	22.5	28.8	30	32.1	37.5	34.2	45	36.0	60	39.4	75	42.5	90	44.9
30	7	4.5	11.9	9	17.2	13.5	21.7	18	25.2	27	28.8	36	32.1	45	34.2	54	36.0	72	39.4	90	42.5	108	44.9
35	7	5.25	11.9	10.5	17.2	15.75	21.7	21	25.2	31.5	28.8	42	32.1	52.5	34.2	63	36.0	84	39.4	105	42.5	126	44.9
40	6	6	10.2	12	14.7	18	18.6	24	21.6	36	24.7	48	27.5	60	29.3	72	30.9	96	33.8	120	36.4	144	38.5
45	7	6.75	11.9	13.5	17.2	20.25	21.7	27	25.2	40.5	28.8	54	32.1	67.5	34.2	81	36.0	108	39.4	135	42.5	162	44.9
50	5	7.5	8.5	15	12.3	22.5	15.5	30	18.0	45	20.5	60	22.9	75	24.4	90	25.7	120	28.1	150	30.4	180	32.1
55	6	8.25	10.2	16.5	14.7	24.75	18.6	33	21.6	49.5	24.7	66	27.5	82.5	29.3	99	30.9	132	33.8	165	36.4	198	38.5
60	5	9	8.5	18	12.3	27	15.5	36	18.0	54	20.5	72	22.9	90	24.4	108	25.7	144	28.1	180	30.4	216	32.1
65	5	9.75	8.5	19.5	12.3	29.25	15.5	39	18.0	58.5	20.5	78	22.9	97.5	24.4	117	25.7	156	28.1	195	30.4	234	32.1
70	5	10.5	8.5	21	12.3	31.5	15.5	42	18.0	63	20.5	84	22.9	105	24.4	126	25.7	168	28.1	210	30.4	252	32.1
75	4	11.25	6.8	22.5	9.8	33.75	12.4	45	14.4	67.5	16.4	90	18.3	112.5	19.5	135	20.6	180	22.5	225	24.3	270	25.7
80	3	12	5.1	24	7.4	36	9.3	48	10.8	72	12.3	96	13.8	120	14.7	144	15.4	192	16.9	240	18.2	288	19.3
85	3	12.75	5.1	25.5	7.4	38.25	9.3	51	10.8	76.5	12.3	102	13.8	127.5	14.7	153	15.4	204	16.9	255	18.2	306	19.3
90	2	13.5	3.4	27	4.9	40.5	6.2	54	7.2	81	8.2	108	9.2	135	9.8	162	10.3	216	11.3	270	12.1	324	12.8
95	2	14.25	3.4	28.5	4.9	42.75	6.2	57	7.2	85.5	8.2	114	9.2	142.5	9.8	171	10.3	228	11.3	285	12.1	342	12.8
100	1	15	1.7	30	2.5	45	3.1	60	3.6	90	4.1	120	4.6	150	4.9	180	5.1	240	5.6	300	6.1	360	6.4

6873 - North Bellbird

PMP Estimation

O:\6873-01_ North Bellbird - Floodplain Management Plan & DCP (BP)\PMP\[pmp data.xls]Temporal Distribution
KEM 11/5/07

Ellipse
B

	Duration (hr)	0.25		0.5		0.75		1		1.5		2		2.5		3		4		5		6	
	PMP (mm)	145		215		274		322		368		413		439		460		511		550		583	
% of time	% of PMP	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)	Time (min)	Cumulative Precipitation (mm)
0	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	4	0.75	5.8	1.5	8.6	2.25	11.0	3	12.9	4.5	14.7	6	16.5	7.5	17.6	9	18.4	12	20.4	15	22.0	18	23.3
10	10	1.5	14.5	3	21.5	4.5	27.4	6	32.2	9	36.8	12	41.3	15	43.9	18	46.0	24	51.1	30	55.0	36	58.3
15	18	2.25	26.1	4.5	38.7	6.75	49.3	9	58.0	13.5	66.2	18	74.3	22.5	79.1	27	82.9	36	92.0	45	98.9	54	105.0
20	25	3	36.3	6	53.8	9	68.5	12	80.5	18	92.0	24	103.2	30	109.8	36	115.1	48	127.8	60	137.4	72	145.8
25	32	3.75	46.5	7.5	68.8	11.25	87.7	15	103.0	22.5	117.7	30	132.1	37.5	140.6	45	147.3	60	163.6	75	175.9	90	186.6
30	39	4.5	56.6	9	83.9	13.5	106.9	18	125.6	27	143.5	36	161.0	45	171.3	54	179.6	72	199.3	90	214.4	108	227.4
35	46	5.25	66.8	10.5	99.0	15.75	126.1	21	148.1	31.5	169.2	42	189.9	52.5	202.1	63	211.8	84	235.1	105	252.8	126	268.2
40	52	6	75.5	12	111.9	18	142.5	24	167.4	36	191.3	48	214.7	60	228.4	72	239.4	96	265.8	120	285.8	144	303.2
45	59	6.75	85.7	13.5	126.9	20.25	161.7	27	190.0	40.5	217.1	54	243.5	67.5	259.2	81	271.6	108	301.6	135	324.3	162	344.0
50	64	7.5	93.0	15	137.7	22.5	175.4	30	206.1	45	235.5	60	264.2	75	281.1	90	294.6	120	327.1	150	351.8	180	373.2
55	70	8.25	101.7	16.5	150.6	24.75	191.9	33	225.4	49.5	257.5	66	289.0	82.5	307.5	99	322.3	132	357.8	165	384.8	198	408.2
60	75	9	108.9	18	161.4	27	205.6	36	241.5	54	275.9	72	309.6	90	329.5	108	345.3	144	383.4	180	412.2	216	437.3
65	80	9.75	116.2	19.5	172.1	29.25	219.3	39	257.6	58.5	294.3	78	330.2	97.5	351.4	117	368.3	156	408.9	195	439.7	234	466.5
70	85	10.5	123.5	21	182.9	31.5	233.0	42	273.7	63	312.7	84	350.9	105	373.4	126	391.3	168	434.5	210	467.2	252	495.6
75	89	11.25	129.3	22.5	191.5	33.75	243.9	45	286.6	67.5	327.5	90	367.4	112.5	391.0	135	409.7	180	454.9	225	489.2	270	519.0
80	92	12	133.6	24	197.9	36	252.1	48	296.2	72	338.5	96	379.8	120	404.1	144	423.6	192	470.3	240	505.7	288	536.5
85	95	12.75	138.0	25.5	204.4	38.25	260.4	51	305.9	76.5	349.5	102	392.2	127.5	417.3	153	437.4	204	485.6	255	522.2	306	553.9
90	97	13.5	140.9	27	208.7	40.5	265.9	54	312.3	81	356.9	108	400.4	135	426.1	162	446.6	216	495.8	270	533.2	324	565.6
95	99	14.25	143.8	28.5	213.0	42.75	271.3	57	318.8	85.5	364.2	114	408.7	142.5	434.9	171	455.8	228	506.0	285	544.2	342	577.3
100	100	15	145.2	30	215.1	45	274.1	60	322.0	90	367.9	120	412.8	150	439.3	180	460.4	240	511.2	300	549.7	360	583.1

% of time	% of PMP	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)	Time (min)	Incremental Precipitation (mm)
0	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	4	0.75	5.8	1.5	8.6	2.25	11.0	3	12.9	4.5	14.7	6	16.5	7.5	17.6	9	18.4	12	20.4	15	22.0	18	23.3
10	6	1.5	8.7	3	12.9	4.5	16.4	6	19.3	9	22.1	12	24.8	15	26.4	18	27.6	24	30.7	30	33.0	36	35.0
15	8	2.25	11.6	4.5	17.2	6.75	21.9	9	25.8	13.5	29.4	18	33.0	22.5	35.1	27	36.8	36	40.9	45	44.0	54	46.6
20	7	3	10.2	6	15.1	9	19.2	12	22.5	18	25.8	24	28.9	30	30.7	36	32.2	48	35.8	60	38.5	72	40.8
25	7	3.75	10.2	7.5	15.1	11.25	19.2	15	22.5	22.5	25.8	30	28.9	37.5	30.7	45	32.2	60	35.8	75	38.5	90	40.8
30	7	4.5	10.2	9	15.1	13.5	19.2	18	22.5	27	25.8	36	28.9	45	30.7	54	32.2	72	35.8	90	38.5	108	40.8
35	7	5.25	10.2	10.5	15.1	15.75	19.2	21	22.5	31.5	25.8	42	28.9	52.5	30.7	63	32.2	84	35.8	105	38.5	126	40.8
40	6	6	8.7	12	12.9	18	16.4	24	19.3	36	22.1	48	24.8	60	26.4	72	27.6	96	30.7	120	33.0	144	35.0
45	7	6.75	10.2	13.5	15.1	20.25	19.2	27	22.5	40.5	25.8	54	28.9	67.5	30.7	81	32.2	108	35.8	135	38.5	162	40.8
50	5	7.5	7.3	15	10.8	22.5	13.7	30	16.1	45	18.4	60	20.6	75	22.0	90	23.0	120	25.6	150	27.5	180	29.2
55	6	8.25	8.7	16.5	12.9	24.75	16.4	33	19.3	49.5	22.1	66	24.8	82.5	26.4	99	27.6	132	30.7	165	33.0	198	35.0
60	5	9	7.3	18	10.8	27	13.7	36	16.1	54	18.4	72	20.6	90	22.0	108	23.0	144	25.6	180	27.5	216	29.2
65	5	9.75	7.3	19.5	10.8	29.25	13.7	39	16.1	58.5	18.4	78	20.6	97.5	22.0	117	23.0	156	25.6	195	27.5	234	29.2
70	5	10.5	7.3	21	10.8	31.5	13.7	42	16.1	63	18.4	84	20.6	105	22.0	126	23.0	168	25.6	210	27.5	252	29.2
75	4	11.25	5.8	22.5	8.6	33.75	11.0	45	12.9	67.5	14.7	90	16.5	112.5	17.6	135	18.4	180	20.4	225	22.0	270	23.3
80	3	12	4.4	24	6.5	36	8.2	48	9.7	72	11.0	96	12.4	120	13.2	144	13.8	192	15.3	240	16.5	288	17.5
85	3	12.75	4.4	25.5	6.5	38.25	8.2	51	9.7	76.5	11.0	102	12.4	127.5	13.2	153	13.8	204	15.3	255	16.5	306	17.5
90	2	13.5	2.9	27	4.3	40.5	5.5	54	6.4	81	7.4	108	8.3	135	8.8	162	9.2	216	10.2	270	11.0	324	11.7
95	2	14.25	2.9	28.5	4.3	42.75	5.5	57	6.4	85.5	7.4	114	8.3	142.5	8.8	171	9.2	228	10.2	285	11.0	342	11.7
100	1	15	1.5	30	2.2	45	2.7	60	3.2	90	3.7	120	4.1	150	4.4	180	4.6	240	5.1	300	5.5	360	5.8

6873 - North Bellbird
PMP Estimation
O:\6873-01_ North Bellbird - Floodplain Management Plan & DCP (BP)\PMP\[pmp data.xls]Spatial Distribution
KEM 11/5/07

Duration (hr) 0.25

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse ($mm.km^2$)**	**Rainfall volume between ellipses ($mm.km^2$)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	232.0	204.0	232	169	408	408	169
B	15820176	13.4	15.8	204.0	177.0	204	149	2356	1947	145
C	29257850	13.8	**29.3**	193.0	193.0	193	**141**	4122	1766	128
D										
E										
F										

Duration (hr) 0.5

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse ($mm.km^2$)**	**Rainfall volume between ellipses ($mm.km^2$)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	336.0	301.0	336	245	592	592	245
B	15820176	13.4	15.8	301.0	260.0	301	220	3476	2885	215
C	29257850	13.8	**29.3**	285.0	285.0	285	**208**	6087	2611	189
D										
E										
F										

Duration (hr) 0.75

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse ($mm.km^2$)**	**Rainfall volume between ellipses ($mm.km^2$)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	425.0	383.0	425	310	748	748	310
B	15820176	13.4	15.8	383.0	330.0	383	280	4423	3675	274
C	29257850	13.8	**29.3**	362.0	362.0	362	**264**	7732	3309	239
D										
E										
F										

Duration (hr) 1

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse ($mm.km^2$)**	**Rainfall volume between ellipses ($mm.km^2$)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	493.0	449.0	493	360	868	868	360
B	15820176	13.4	15.8	449.0	397.0	449	328	5185	4317	322
C	29257850	13.8	**29.3**	427.0	427.0	427	**312**	9120	3935	284
D										
E										
F										

Duration (hr) 1.5

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse (mm.km^2)**	**Rainfall volume between ellipses (mm.km^2)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	563.0	575.0	563	411	991	991	411
B	15820176	13.4	15.8	513.0	511.0	513	374	5924	4933	368
C	29257850	13.8	**29.3**	480.0	550.0	480	**350**	10252	4327	313
D										
E										
F										

Duration (hr) 2

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse (mm.km^2)**	**Rainfall volume between ellipses (mm.km^2)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	628.0	672.0	628	458	1106	1106	458
B	15820176	13.4	15.8	575.0	590.0	575	420	6641	5535	413
C	29257850	13.8	**29.3**	550.0	640.0	550	**402**	11747	5107	369
D										
E										
F										

Duration (hr) 2.5

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse (mm.km^2)**	**Rainfall volume between ellipses (mm.km^2)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	669.0	742.0	669	488	1178	1178	488
B	15820176	13.4	15.8	612.0	663.0	612	447	7068	5890	439
C	29257850	13.8	**29.3**	585.0	710.0	585	**427**	12495	5427	392
D										
E										
F										

Duration (hr) 3

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse (mm.km^2)**	**Rainfall volume between ellipses (mm.km^2)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	705.0	810.0	705	515	1241	1241	515
B	15820176	13.4	15.8	642.0	717.0	642	469	7414	6173	460
C	29257850	13.8	**29.3**	615.0	770.0	615	**449**	13135	5721	413
D										
E										
F										

Duration (hr) 4

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse ($mm.km^2$)**	**Rainfall volume between ellipses ($mm.km^2$)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	771.0	926.0	771	563	1357	1357	563
B	15820176	13.4	15.8	711.0	811.0	711	519	8211	6854	511
C	29257850	13.8	**29.3**	685.0	880.0	685	**500**	14630	6419	464
D										
E										
F										

Duration (hr) 5

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse ($mm.km^2$)**	**Rainfall volume between ellipses ($mm.km^2$)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	832.0	1018.0	832	607	1465	1465	607
B	15820176	13.4	15.8	765.0	890.0	765	558	8835	7370	550
C	29257850	13.8	**29.3**	737.0	965.0	737	**538**	15741	6906	499
D										
E										
F										

Duration (hr) 6

		b	c			d	e	f	g	h
Step 1		Step 2	Step 3			Step 4	Step 5	Step 6	Step 7	Step 8
Ellipse	**Catchment area between ellipses (m^2)**	**Catchment area between ellipses (km^2)**	**Catchment area enclosed by ellipse (km^2)**	**D_S (mm)**	**D_R (mm)**	**Initial mean rainfall depth (mm)**	**Adjusted mean rainfall depth (mm)**	**Rainfall volume enclosed by ellipse ($mm.km^2$)**	**Rainfall volume between ellipses ($mm.km^2$)**	**Mean rainfall depth between ellipses (mm)**
A	2411916	2.4	2.4	879.0	1084.0	879	642	1548	1548	642
B	15820176	13.4	15.8	811.0	950.0	811	592	9366	7818	583
C	29257850	13.8	**29.3**	781.0	1030.0	781	**570**	16681	7315	529
D										
E										
F										

APPENDIX D – HEC-RAS BOUNDARY CONDITIONS

Adopted peak flows for developed State HEC-RAS Steady State Hydraulics model

			Flow m3/s			
River	**Reach**	**RS**	**5 year**	**20 Year**	**50 Year**	**100 Year**
0	20	1410	14.0	19.1	21.8	24.7
1	3412	6338	21.1	30.3	35.3	40.5
1	1577	3186	34.4	49.8	58.9	67.8
1	0	1274	77.4	110.8	130.1	148.8
2	537	2443	2.3	3.4	4.1	4.7
2	157	261	9.0	12.6	14.6	16.8
3	126	1235	6.6	9.2	10.7	12.3
4	5123	6212	8.2	11.8	13.9	16.0
4	4350	4931	11.0	15.8	18.5	21.3
4	998	4117	35.4	50.4	58.5	66.9
4	97	793	39.9	56.7	66.0	75.3
5	883	2047	20.6	29.6	34.6	39.7
5	287	584	22.0	31.5	36.7	42.0
5	35	140	23.9	33.9	39.5	45.2
6	136	620	1.2	1.7	2.0	2.3
7	128	1154	2.3	3.2	3.6	4.1
8	84	712	2.2	3.0	3.5	4.0
9	130	241	3.0	4.2	4.9	5.5

Adopted peak flows for PMF HEC-RAS Steady State Hydraulics model

River	Reach	RS	PMF (m3/s)
0	20	1410	212
1	3412	6338	488
1	3035	3169	407
1	0	2718	1120
2	537	2443	103
2	157	261	175
3	126	1235	108
4	3327	4416	142
4	2554	3134	192
4	365	2321	636
5	883	2047	381
5	287	584	393
5	35	140	414
6	136	620	20
7	128	1154	34
8	84	712	41

Adopted Downstream Tailwater Level on Bellbird Creek

	TWL (m AHD)
5 year	74.15
20 Year	74.59
50 Year	75.26
100 Year	75.52
PMF	81.4

APPENDIX E – HEC-RAS PARAMETERS

Channel Roughness - Developed State Model

River	Reach	River Station	Left Overbank	Channel Mannings 'n'	Right Over Bank
0	20	1410.1	0.05	0.07	0.05
0	20	1100.46	0.05	0.07	0.05
0	20	908.05	0.05	0.07	0.05
0	20	762.98	0.05	0.07	0.05
0	20	625.85	0.05	0.07	0.05
0	20	512.91	0.05	0.07	0.05
0	20	424.95	0.05	0.07	0.05
0	20	327.95	0.05	0.07	0.05
0	20	186.91	0.05	0.07	0.05
0	20	19.82	0.05	0.07	0.05
1	3412	6338	0.05	0.05	0.05
1	3412	5904	0.04	0.05	0.04
1	3412	5846	0.04	0.05	0.04
1	3412	5836	0.04	0.05	0.04
1	3412	5529	0.04	0.06	0.04
1	3412	5519	0.04	0.06	0.04
1	3412	5058	0.04	0.06	0.04
1	3412	4790	0.04	0.06	0.04
1	3412	4780	0.04	0.06	0.04
1	3412	4545	0.035	0.06	0.035
1	3412	4535	0.035	0.06	0.035
1	3412	4266	0.04	0.07	0.04
1	3412	4220	0.04	0.08	0.03
1	3412	4141	0.04	0.05	0.04
1	3412	4135	0.04	0.05	0.04
1	3412	4010	0.03	0.06	0.04
1	3412	3836	0.04	0.06	0.04
1	3412	3691	0.04	0.06	0.04
1	3412	3613	0.04	0.07	0.04
1	3412	3532	0.04	0.07	0.04
1	3412	3412	0.04	0.07	0.04
1	1577	3185.71	0.07	0.08	0.07
1	1577	3035.35	0.05	0.08	0.05
1	1577	2877.57	0.05	0.08	0.05
1	1577	2748.31	0.04	0.1	0.04
1	1577	2685.08	0.04	0.08	0.05
1	1577	2501.79	0.04	0.08	0.05
1	1577	2394.92	0.05	0.08	0.08
1	1577	2384	0.05	0.08	0.08
1	1577	2281.53	0.05	0.08	0.08
1	1577	2152.78	0.05	0.08	0.08
1	1577	1964.44	0.04	0.08	0.05
1	1577	1810.72	0.04	0.08	0.05
1	1577	1577.38	0.04	0.05	0.04
1	1577	1396	0.05	0.07	0.05
1	0	1273.6	0.04	0.05	0.04
1	0	1122.99	0.045	0.04	0.045
1	0	729.84	0.045	0.035	0.045
1	0	566.93	0.045	0.03	0.045
1	0	500.53	0.045	0.025	0.045
1	0	427.63	0.045	0.024	0.045
1	0	359.39	0.045	0.023	0.045
1	0	346.15	0.045	0.022	0.045
1	0	210.03	0.045	0.022	0.045
1	0	92.61	0.045	0.02	0.045
1	0	0	0.045	0.025	0.045

River	Reach	River Station	Left Overbank	Channel Mannings 'n'	Right Over Bank
2	537	2443.45	0.05	0.07	0.05
2	537	2284.88	0.05	0.07	0.05
2	537	2128.69	0.05	0.07	0.05
2	537	1940.92	0.05	0.07	0.05
2	537	1755.04	0.05	0.07	0.05
2	537	1538.74	0.05	0.07	0.05
2	537	1335.64	0.05	0.07	0.05
2	537	1115.38	0.05	0.07	0.05
2	537	925.54	0.05	0.07	0.05
2	537	721.8	0.05	0.07	0.05
2	537	537.21	0.05	0.07	0.05
2	157	260.99	0.06	0.08	0.06
2	157	156.55	0.06	0.08	0.06
3	126	1235.08	0.05	0.07	0.05
3	126	1082.88	0.05	0.07	0.05
3	126	935.46	0.05	0.07	0.05
3	126	770.49	0.05	0.07	0.05
3	126	606.02	0.05	0.07	0.05
3	126	524.98	0.05	0.07	0.05
3	126	505.92	0.05	0.07	0.05
3	126	289.48	0.05	0.07	0.05
3	126	125.72	0.05	0.07	0.05
4	5123	6211.75	0.07	0.1	0.07
4	5123	6113.46	0.07	0.1	0.07
4	5123	6020.9	0.07	0.1	0.07
4	5123	5901.83	0.07	0.1	0.07
4	5123	5785.71	0.07	0.1	0.07
4	5123	5653.04	0.07	0.1	0.07
4	5123	5539.2	0.07	0.1	0.07
4	5123	5408.69	0.07	0.1	0.07
4	5123	5276.37	0.07	0.1	0.07
4	5123	5123.42	0.07	0.1	0.07
4	4350	4930.62	0.07	0.1	0.07
4	4350	4707.35	0.07	0.1	0.07
4	4350	4568.03	0.07	0.1	0.07
4	4350	4350.2	0.07	0.1	0.07
4	998	4117.06	0.05	0.07	0.05
4	998	3953.34	0.05	0.07	0.05
4	998	3747.08	0.05	0.07	0.05
4	998	3280.72	0.05	0.07	0.05
4	998	3076.33	0.05	0.07	0.05
4	998	3060	0.05	0.07	0.05
4	998	2821.02	0.05	0.07	0.05
4	998	2609.13	0.05	0.07	0.05
4	998	2351.97	0.05	0.07	0.05
4	998	2208.09	0.05	0.07	0.05
4	998	2128.51	0.05	0.07	0.05
4	998	1925.64	0.05	0.07	0.05
4	998	1751.07	0.05	0.07	0.05
4	998	1584.49	0.05	0.07	0.05
4	998	1448.28	0.05	0.07	0.05
4	998	1395.18	0.05	0.07	0.05
4	998	1378.46	0.05	0.07	0.05
4	998	1190.83	0.05	0.07	0.05
4	998	997.99	0.05	0.07	0.05
4	97	793.4	0.05	0.07	0.05
4	97	622.77	0.05	0.07	0.05
4	97	466.3	0.04	0.05	0.04
4	97	97.48	0.05	0.07	0.05

River	Reach	River Station	Left Overbank	Channel Mannings 'n'	Right Over Bank
5	883	2046.72	0.05	0.07	0.05
5	883	1964.51	0.05	0.07	0.05
5	883	1859.76	0.05	0.07	0.05
5	883	1769.01	0.05	0.07	0.05
5	883	1665.27	0.05	0.07	0.05
5	883	1561.13	0.05	0.07	0.05
5	883	1457.84	0.05	0.07	0.05
5	883	1287.21	0.05	0.07	0.05
5	883	1137.7	0.05	0.07	0.05
5	883	883.08	0.05	0.07	0.05
5	287	584	0.05	0.07	0.05
5	287	314.64	0.05	0.07	0.05
5	287	287.07	0.05	0.07	0.05
5	35	139.68	0.05	0.07	0.07
5	35	34.83	0.05	0.07	0.07
6	136	620.35	0.05	0.07	0.05
6	136	508.23	0.05	0.07	0.05
6	136	435.55	0.05	0.07	0.05
6	136	325.77	0.05	0.07	0.05
6	136	221.44	0.05	0.07	0.05
6	136	135.86	0.05	0.07	0.05
7	128	1154.14	0.05	0.07	0.05
7	128	1041.45	0.05	0.07	0.05
7	128	946.58	0.06	0.07	0.06
7	128	763.09	0.06	0.07	0.06
7	128	680.22	0.06	0.07	0.06
7	128	612.82	0.06	0.07	0.06
7	128	433.14	0.05	0.07	0.05
7	128	266.37	0.05	0.07	0.05
7	128	127.73	0.05	0.07	0.05
8	84	711.85	0.7	0.1	0.07
8	84	603.85	0.7	0.1	0.07
8	84	452.28	0.7	0.1	0.07
8	84	333.35	0.7	0.1	0.07
8	84	220.37	0.7	0.1	0.07
8	84	83.73	0.7	0.1	0.07
9	130	241.16	0.05	0.05	0.05
9	130	130.42	0.05	0.05	0.05

Channel Roughness - PMF Model

River	Reach	River Station	Left Overbank	Channel Mannings 'n'	Right Over Bank
0	20	1410.1	0.05	0.07	0.05
0	20	1100.46	0.05	0.07	0.05
0	20	908.05	0.05	0.07	0.05
0	20	762.98	0.05	0.07	0.05
0	20	625.85	0.05	0.07	0.05
0	20	512.91	0.05	0.07	0.05
0	20	424.95	0.05	0.07	0.05
0	20	327.95	0.05	0.07	0.05
0	20	186.91	0.05	0.07	0.05
0	20	19.82	0.05	0.07	0.05
1	3412	6338	0.05	0.05	0.05
1	3412	5904	0.04	0.05	0.04
1	3412	5846	0.04	0.05	0.04
1	3412	5836	0.04	0.05	0.04
1	3412	5529	0.04	0.06	0.04
1	3412	5524			
1	3412	5519	0.04	0.06	0.04
1	3412	5058	0.04	0.06	0.04
1	3412	4790	0.04	0.06	0.04
1	3412	4780	0.04	0.06	0.04
1	3412	4545	0.035	0.06	0.035
1	3412	4535	0.035	0.06	0.035
1	3412	4266	0.04	0.07	0.04
1	3412	4220	0.04	0.08	0.03
1	3412	4141	0.04	0.05	0.04
1	3412	4135	0.04	0.05	0.04
1	3412	4010	0.03	0.06	0.04
1	3412	3836	0.04	0.06	0.04
1	3412	3691	0.04	0.06	0.04
1	3412	3613	0.04	0.07	0.04
1	3412	3532	0.04	0.07	0.04
1	3412	3412	0.04	0.07	0.04
1	3035	3169	0.05	0.08	0.05
1	3035	3035	0.05	0.08	0.05
1	0	2718	0.05	0.07	0.05
1	0	2552	0.05	0.07	0.05
1	0	2415	0.05	0.07	0.05
1	0	2275	0.05	0.07	0.05
1	0	2142	0.05	0.07	0.05
1	0	2000	0.05	0.07	0.05
1	0	1819	0.05	0.07	0.05
1	0	1602	0.05	0.07	0.05
1	0	1273.6	0.04	0.05	0.04
1	0	1122.99	0.045	0.04	0.045
1	0	729.84	0.045	0.035	0.045
1	0	566.93	0.045	0.03	0.045
1	0	500.53	0.045	0.025	0.045
1	0	427.63	0.045	0.024	0.045
1	0	359.39	0.045	0.023	0.045
1	0	346.15	0.045	0.022	0.045
1	0	210.03	0.045	0.022	0.045
1	0	92.61	0.045	0.02	0.045
1	0	0	0.045	0.025	0.045

River	Reach	River Station	Left Overbank	Channel	Right Over Bank
				Mannings 'n'	
2	537	2443.45	0.05	0.07	0.05
2	537	2284.88	0.05	0.07	0.05
2	537	2128.69	0.05	0.07	0.05
2	537	1940.92	0.05	0.07	0.05
2	537	1755.04	0.05	0.07	0.05
2	537	1538.74	0.05	0.07	0.05
2	537	1335.64	0.05	0.07	0.05
2	537	1115.38	0.05	0.07	0.05
2	537	925.54	0.05	0.07	0.05
2	537	721.8	0.05	0.07	0.05
2	537	537.21	0.05	0.07	0.05
2	157	260.99	0.06	0.08	0.06
2	157	156.55	0.06	0.08	0.06
3	126	1235.08	0.05	0.07	0.05
3	126	1082.88	0.05	0.07	0.05
3	126	935.46	0.05	0.07	0.05
3	126	770.49	0.05	0.07	0.05
3	126	606.02	0.05	0.07	0.05
3	126	524.98	0.05	0.07	0.05
3	126	505.92	0.05	0.07	0.05
3	126	289.48	0.05	0.07	0.05
3	126	125.72	0.05	0.07	0.05
4	3327	4415.58	0.05	0.08	0.05
4	3327	4317.29	0.05	0.08	0.05
4	3327	4224.73	0.05	0.08	0.05
4	3327	4105.66	0.05	0.08	0.05
4	3327	3989.54	0.05	0.08	0.05
4	3327	3856.87	0.05	0.08	0.05
4	3327	3743.03	0.05	0.08	0.05
4	3327	3612.52	0.05	0.08	0.05
4	3327	3480.2	0.05	0.08	0.05
4	3327	3327.25	0.05	0.08	0.05
4	2554	3134.45	0.05	0.08	0.05
4	2554	2911.18	0.05	0.08	0.05
4	2554	2771.86	0.05	0.08	0.05
4	2554	2554.03	0.05	0.08	0.05
4	365	2320.86	0.05	0.07	0.05
4	365	2157.14	0.05	0.07	0.05
4	365	1954.29	0.05	0.07	0.05
4	365	1486.1	0.05	0.07	0.05
4	365	1279.22	0.05	0.07	0.05
4	365	1023.34	0.05	0.07	0.05
4	365	814.66	0.05	0.07	0.05
4	365	519.85	0.05	0.07	0.05
4	365	365.4	0.05	0.07	0.05

River	Reach	River Station	Left Overbank	Channel Mannings 'n'	Right Over Bank
5	883	2046.72	0.05	0.07	0.05
5	883	1964.51	0.05	0.07	0.05
5	883	1859.76	0.05	0.07	0.05
5	883	1769.01	0.05	0.07	0.05
5	883	1665.27	0.05	0.07	0.05
5	883	1561.13	0.05	0.07	0.05
5	883	1457.84	0.05	0.07	0.05
5	883	1287.21	0.05	0.07	0.05
5	883	1137.7	0.05	0.07	0.05
5	883	883.08	0.05	0.07	0.05
5	287	584	0.05	0.07	0.05
5	287	314.64	0.05	0.07	0.05
5	287	287.07	0.05	0.07	0.05
5	35	139.68	0.05	0.07	0.07
5	35	34.83	0.05	0.07	0.07
6	136	620.35	0.05	0.07	0.05
6	136	508.23	0.05	0.07	0.05
6	136	435.55	0.05	0.07	0.05
6	136	325.77	0.05	0.07	0.05
6	136	221.44	0.05	0.07	0.05
6	136	135.86	0.05	0.07	0.05
7	128	1154.14	0.05	0.07	0.05
7	128	1041.45	0.05	0.07	0.05
7	128	946.58	0.06	0.07	0.06
7	128	763.09	0.06	0.07	0.06
7	128	680.22	0.06	0.07	0.06
7	128	612.82	0.06	0.07	0.06
7	128	433.14	0.05	0.07	0.05
7	128	266.37	0.05	0.07	0.05
7	128	127.73	0.05	0.07	0.05
8	84	711.85	0.7	0.1	0.07
8	84	603.85	0.7	0.1	0.07
8	84	452.28	0.7	0.1	0.07
8	84	333.35	0.7	0.1	0.07
8	84	220.37	0.7	0.1	0.07
8	84	83.73	0.7	0.1	0.07

APPENDIX F – HEC-RAS RESULTS

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)
0	20	19.82	5 year	13.98	79.89	80.35	80.17	80.37	0.010016	0.73	19.11	54.04
0	20	19.82	20 Year	19.12	79.89	80.42	80.22	80.46	0.010009	0.83	23.2	55.09
0	20	20	50 Year	21.8	79.9	80.5	80.24	80.5	0.010002	0.87	25.17	55.52
0	20	20	100 Year	24.7	79.9	80.5	80.26	80.53	0.010003	0.92	27.15	55.95
0	20	187	5 year	14.0	81.9	82.3	82.17	82.34	0.014028	0.81	17.24	52.51
0	20	187	20 Year	19.1	81.9	82.4	82.22	82.42	0.014007	0.92	20.91	54.58
0	20	187	50 Year	21.8	81.9	82.4	82.23	82.46	0.014078	0.97	22.65	54.96
0	20	187	100 Year	24.7	81.9	82.4	82.26	82.5	0.014027	1.02	24.45	55.37
0	20	328	5 year	14.0	83.5	84.3	84.18	84.36	0.014329	1.15	13.49	39.06
0	20	328	20 Year	19.1	83.5	84.4	84.25	84.45	0.014403	1.26	16.99	44.89
0	20	328	50 Year	21.8	83.5	84.4	84.28	84.5	0.014415	1.31	18.78	48.02
0	20	328	100 Year	24.7	83.5	84.5	84.31	84.54	0.014515	1.37	20.56	50.89
0	20	425	5 year	14.0	84.9	85.5	85.25	85.55	0.01081	1.01	13.94	26.4
0	20	425	20 Year	19.1	84.9	85.6	85.33	85.67	0.011157	1.15	16.82	27.6
0	20	425	50 Year	21.8	84.9	85.7	85.36	85.72	0.011371	1.22	18.18	28.14
0	20	425	100 Year	24.7	84.9	85.7	85.4	85.78	0.011491	1.28	19.59	28.69
0	20	512.91	5 year	13.98	84.88	85.84	85.25	85.86	0.001733	0.57	30.71	119.36
0	20	512.91	20 Year	19.12	84.88	85.94	85.33	85.96	0.001542	0.58	47.24	168.76
0	20	512.91	50 Year	21.81	84.88	85.99	85.38	86	0.001415	0.57	54.75	170.02
0	20	512.91	100 Year	24.65	84.88	86.03	85.41	86.04	0.001306	0.56	62.16	171.28
0	20	626	5 year	13.98	86.55	86.87	86.87	86.98	0.067077	1.45	9.85	46.2
0	20	626	20 Year	19.12	86.55	86.92	86.92	87.05	0.064735	1.61	12.22	49.21
0	20	626	50 Year	21.81	86.55	86.95	86.95	87.09	0.058911	1.64	13.74	51.05
0	20	626	100 Year	24.65	86.55	86.97	86.97	87.12	0.06013	1.73	14.8	52.23
0	20	763	5 year	13.98	86.86	87.73	87.26	87.75	0.001886	0.55	25.92	41.61
0	20	763	20 Year	19.12	86.86	87.87	87.33	87.89	0.002108	0.64	32.13	50.89
0	20	763	50 Year	21.81	86.86	87.93	87.36	87.95	0.002201	0.68	35.34	60.5
0	20	763	100 Year	24.65	86.86	87.99	87.39	88.01	0.002293	0.72	38.9	71.66
0	20	908	5 year	13.98	89.06	89.45	89.45	89.55	0.047188	1.53	10.1	49.05
0	20	908	20 Year	19.12	89.06	89.51	89.51	89.62	0.044577	1.65	13	56.11
0	20	908	50 Year	21.81	89.06	89.53	89.53	89.65	0.044957	1.71	14.33	59.41
0	20	908	100 Year	24.65	89.06	89.56	89.56	89.68	0.043071	1.75	15.98	63.28
0	20	1100.46	5 year	13.98	92.12	92.68	92.51	92.7	0.008153	0.79	19.88	70.04
0	20	1100.46	20 Year	19.12	92.12	92.74	92.57	92.77	0.008328	0.87	24.67	76.93
0	20	1100.46	50 Year	21.81	92.12	92.77	92.59	92.81	0.008333	0.9	27.1	80.23
0	20	1100.46	100 Year	24.65	92.12	92.8	92.62	92.84	0.008471	0.94	29.47	83.9
0	20	1410.1	5 year	13.98	97.71	98.1	98.1	98.21	0.050066	1.5	10.23	49.37
0	20	1410.1	20 Year	19.12	97.71	98.16	98.16	98.27	0.049228	1.64	12.94	55.95
0	20	1410.1	50 Year	21.81	97.71	98.18	98.18	98.31	0.046585	1.67	14.56	59.99
0	20	1410.1	100 Year	24.65	97.71	98.21	98.21	98.34	0.045424	1.72	16.1	63.57

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
1	0	0	5 year	77.44	70.64	74.15	73.16	74.48	0.001334	2.53	30.56	73.07
1	0	0	20 Year	110.83	70.64	74.59	73.63	75.08	0.001628	3.1	35.7	110.86
1	0	0	50 Year	130.07	70.64	75.26	73.87	75.72	0.001158	2.99	43.52	148.76
1	0	0	100 Year	148.82	70.64	75.52	74.08	76.04	0.001211	3.2	46.55	167.26
1	0	92.61	5 year	77.44	70.94	74.25	73.57	74.69	0.001603	2.94	26.38	13.98
1	0	92.61	20 Year	110.83	70.94	74.71	74.12	75.31	0.001804	3.42	32.44	23.98
1	0	92.61	50 Year	130.07	70.94	75.35	74.38	75.85	0.001174	3.15	41.34	212.32
1	0	92.61	100 Year	148.82	70.94	75.62	74.61	76.17	0.00115	3.3	45.09	291.07
1	0	210.03	5 year	77.44	71.39	74.43	73.99	75.04	0.002391	3.49	23.34	15.82
1	0	210.03	20 Year	110.83	71.39	74.91	74.65	75.7	0.002483	4.03	32.46	20.96
1	0	210.03	50 Year	130.07	71.39	75.47	74.94	76.13	0.001693	3.75	46.35	29.88
1	0	210.03	100 Year	148.82	71.39	75.74	75.11	76.42	0.001628	3.87	55.29	38.77
1	0	346.15	5 year	77.44	72	74.6	74.6	75.52	0.004987	4.24	18.26	10.05
1	0	346.15	20 Year	110.83	72	75.2	75.2	76.21	0.004771	4.45	24.91	12.44
1	0	346.15	50 Year	130.07	72	75.47	75.47	76.53	0.004699	4.56	28.5	13.58
1	0	346.15	100 Year	148.82	72	75.76	75.76	76.82	0.004608	4.55	32.69	15.59
1	0	359.39	5 year	77.44	72.1	75.55	74.72	75.86	0.001681	2.49	31.08	16.73
1	0	359.39	20 Year	110.83	72.1	76.25	75.27	76.57	0.001403	2.5	44.3	20.94
1	0	359.39	50 Year	130.07	72.1	76.58	75.52	76.91	0.0012	2.53	52.31	28.01
1	0	359.39	100 Year	148.82	72.1	76.84	75.73	77.18	0.001114	2.6	60.19	34.21
1	0	427.63	5 year	77.44	72.35	75.63	74.97	76.02	0.00233	2.76	28.01	15.34
1	0	427.63	20 Year	110.83	72.35	76.32	75.51	76.7	0.00203	2.71	41.2	24.01
1	0	427.63	50 Year	130.07	72.35	76.65	75.81	77.02	0.00172	2.69	50.02	29.96
1	0	427.63	100 Year	148.82	72.35	76.9	76.04	77.28	0.001529	2.73	58.13	34.71
1	0	500.53	5 year	77.44	72.65	76.09	75.38	76.29	0.00183	1.99	38.92	29.24
1	0	500.53	20 Year	110.83	72.65	76.77	75.81	76.93	0.001069	1.79	61.92	36.71
1	0	500.53	50 Year	130.07	72.65	77.07	75.99	77.23	0.000904	1.77	73.34	38.93
1	0	500.53	100 Year	148.82	72.65	77.32	76.15	77.49	0.000819	1.78	83.42	40.78
1	0	566.93	5 year	77.44	72.9	76.2		76.48	0.003101	2.32	33.37	21.9
1	0	566.93	20 Year	110.83	72.9	76.81		77.07	0.002459	2.3	48.23	27.29
1	0	566.93	50 Year	130.07	72.9	77.09		77.36	0.002236	2.31	56.28	29.49
1	0	566.93	100 Year	148.82	72.9	77.33		77.61	0.002069	2.34	63.8	33.94
1	0	729.84	5 year	77.44	73.52	76.72	75.9	76.92	0.002563	2	38.74	22.53
1	0	729.84	20 Year	110.83	73.52	77.29	76.27	77.51	0.003123	2.06	53.68	35.03
1	0	729.84	50 Year	130.07	73.52	77.58	76.46	77.78	0.003133	1.98	65.56	45.92
1	0	729.84	100 Year	148.82	73.52	77.79	76.63	77.99	0.002743	1.96	75.84	48.93
1	0	1122.99	5 year	77.44	74.49	77.64		77.88	0.007768	2.16	35.86	35.77
1	0	1122.99	20 Year	110.83	74.49	78.15		78.36	0.0044	2.02	54.87	39.49
1	0	1122.99	50 Year	130.07	74.49	78.37		78.58	0.00388	2.04	63.74	41.1
1	0	1122.99	100 Year	148.82	74.49	78.51	77.85	78.75	0.003885	2.13	69.8	42.17
1	0	1273.6	5 year	77.44	76.42	78.82	78.43	79.18	0.01061	2.63	29.42	19.65
1	0	1273.6	20 Year	110.83	76.42	79	78.8	79.57	0.017932	3.35	33.12	22.96
1	0	1273.6	50 Year	130.07	76.42	79.1	79.06	79.78	0.020781	3.66	35.63	26.77
1	0	1273.6	100 Year	148.82	76.42	79.29	79.29	79.97	0.018306	3.67	41.72	36.96

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
1	1577	1396	5 year	34.44	77.69	79.98		80.04	0.005724	1.16	29.77	26.48
1	1577	1396	20 Year	49.8	77.69	80.43		80.49	0.003248	1.09	52.92	86.31
1	1577	1396	50 Year	58.94	77.69	80.61		80.66	0.00259	1.04	69.52	105.82
1	1577	1396	100 Year	67.75	77.69	80.72		80.77	0.002331	1.03	85.75	157.05
1	1577	1577.38	5 year	34.44	77.62	80.63	79.78	80.66	0.002269	0.78	44.33	58.84
1	1577	1577.38	20 Year	49.8	77.62	80.96	80.05	80.97	0.000646	0.42	128.07	234.9
1	1577	1577.38	50 Year	58.94	77.62	80.92	80.16	80.94	0.001129	0.54	119.31	233.48
1	1577	1577.38	100 Year	67.75	77.62	81	80.24	81.01	0.000982	0.54	136.4	236.24
1	1577	1810.72	5 year	34.44	79.3	81.01	80.47	81.04	0.001605	0.57	45.41	54.2
1	1577	1810.72	20 Year	49.8	79.3	81.14	80.58	81.19	0.002126	0.7	52.27	55.27
1	1577	1810.72	50 Year	58.94	79.3	81.2	80.65	81.26	0.002446	0.78	55.58	55.83
1	1577	1810.72	100 Year	67.75	79.3	81.25	80.7	81.32	0.002762	0.84	58.35	56.22
1	1577	1964.44	5 year	34.44	80.07	81.43	80.97	81.47	0.0064	0.94	36.43	60.74
1	1577	1964.44	20 Year	49.8	80.07	81.64	81.08	81.7	0.006284	1.07	46.08	65.36
1	1577	1964.44	50 Year	58.94	80.07	81.75	81.15	81.82	0.006297	1.14	51.15	67.69
1	1577	1964.44	100 Year	67.75	80.07	81.85	81.21	81.92	0.006347	1.2	55.68	69.72
1	1577	2152.78	5 year	34.44	81.09	82.91		83.02	0.010665	1.42	25.38	55.77
1	1577	2152.78	20 Year	49.8	81.09	83.1		83.19	0.010053	1.46	43.45	121.69
1	1577	2152.78	50 Year	58.94	81.09	83.18	82.95	83.26	0.009387	1.44	53.06	132.42
1	1577	2152.78	100 Year	67.75	81.09	83.24	83.1	83.32	0.008652	1.41	61.74	135.64
1	1577	2281.53	5 year	34.44	81.4	83.8		83.82	0.001551	0.71	62.37	101.22
1	1577	2281.53	20 Year	49.8	81.4	83.97		83.99	0.001623	0.77	80.14	106.57
1	1577	2281.53	50 Year	58.94	81.4	84.05		84.08	0.001717	0.82	88.91	111.13
1	1577	2281.53	100 Year	67.75	81.4	84.12		84.15	0.00182	0.86	96.42	114.93
1	1577	2384	5 year	34.44	81.67	84.02	83.07	84.08	0.004115	1.06	33.48	25.97
1	1577	2384	20 Year	49.8	81.67	84.21	83.3	84.3	0.005709	1.34	38.79	30.54
1	1577	2384	50 Year	58.94	81.67	84.3	83.42	84.41	0.006563	1.49	41.71	31.45
1	1577	2384	100 Year	67.75	81.67	84.38	83.51	84.51	0.00737	1.63	44.22	31.72
1	1577	2390		Bridge								
1	1577	2394.92	5 year	34.44	81.67	84.11	83.07	84.16	0.003419	1	35.73	27.85
1	1577	2394.92	20 Year	49.8	81.67	84.33	83.3	84.41	0.004435	1.24	42.55	31.54
1	1577	2394.92	50 Year	58.94	81.67	84.45	83.42	84.54	0.004935	1.36	46.19	31.93
1	1577	2394.92	100 Year	67.75	81.67	84.6	83.51	84.7	0.004815	1.42	51.28	32
1	1577	2501.79	5 year	34.44	82.15	84.64	84	84.77	0.010508	1.67	21.63	20.54
1	1577	2501.79	20 Year	49.8	82.15	84.95	84.31	85.11	0.010034	1.84	28.87	25.37
1	1577	2501.79	50 Year	58.94	82.15	85.11	84.48	85.28	0.009805	1.92	32.98	27.73
1	1577	2501.79	100 Year	67.75	82.15	85.25	84.63	85.43	0.009531	1.98	36.94	29.87
1	1577	2685.08	5 year	34.44	82.91	85.76	84.66	85.81	0.003491	0.96	36.58	29.93
1	1577	2685.08	20 Year	49.8	82.91	86.08	84.92	86.14	0.00358	1.11	46.94	35.51
1	1577	2685.08	50 Year	58.94	82.91	86.24	85.06	86.31	0.003637	1.18	53.04	42.19
1	1577	2685.08	100 Year	67.75	82.91	86.37	85.17	86.45	0.003688	1.24	59.09	50.93
1	1577	2748.31	5 year	34.44	81.28	85.92		85.94	0.001272	0.67	53.04	41.87
1	1577	2748.31	20 Year	49.8	81.28	86.25		86.28	0.001337	0.73	69.89	57.55
1	1577	2748.31	50 Year	58.94	81.28	86.42		86.45	0.001282	0.74	79.53	60.29
1	1577	2748.31	100 Year	67.75	81.28	86.55		86.58	0.001258	0.76	87.76	62.54
1	1577	2877.57	5 year	34.44	83.31	86.02		86.03	0.000448	0.38	106.37	144.89
1	1577	2877.57	20 Year	49.8	83.31	86.35		86.35	0.000315	0.36	161.94	185.41
1	1577	2877.57	50 Year	58.94	83.31	86.5		86.51	0.000267	0.35	191.77	193.5
1	1577	2877.57	100 Year	67.75	83.31	86.64		86.64	0.000243	0.34	217.89	201.49
1	1577	3035.35	5 year	34.44	83.86	86.13		86.15	0.002887	0.74	55.4	110.5
1	1577	3035.35	20 Year	49.8	83.86	86.41		86.43	0.001594	0.64	88.43	128.33
1	1577	3035.35	50 Year	58.94	83.86	86.56		86.57	0.001333	0.62	109.03	154.12
1	1577	3035.35	100 Year	67.75	83.86	86.68		86.7	0.001153	0.61	130.3	173.47
1	1577	3185.71	5 year	34.44	84.43	86.72		86.79	0.006806	1.35	33.7	53.28
1	1577	3185.71	20 Year	49.8	84.43	86.82		86.94	0.009994	1.71	39.69	61.18
1	1577	3185.71	50 Year	58.94	84.43	86.91		87.03	0.010715	1.83	45.33	73.62
1	1577	3185.71	100 Year	67.75	84.43	86.99		87.12	0.010935	1.91	51.59	84.65

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1	3412	3412	5 year	21.09	85.34	87.51		87.53	0.001432	0.59	35.5	35.11
1	3412	3412	20 Year	30.34	85.34	87.8		87.82	0.001441	0.64	50.98	84.57
1	3412	3412	50 Year	35.33	85.34	87.89		87.91	0.001393	0.65	59.77	92.7
1	3412	3412	100 Year	40.47	85.34	87.98		88	0.001345	0.66	67.64	95.6
1	3412	3532	5 year	21.09	85.94	87.79		87.84	0.005564	1.05	20.15	20.2
1	3412	3532	20 Year	30.34	85.94	88.07		88.13	0.00551	1.15	27.23	38.52
1	3412	3532	50 Year	35.33	85.94	88.15		88.23	0.005563	1.21	30.86	44.52
1	3412	3532	100 Year	40.47	85.94	88.23		88.3	0.005681	1.27	34.31	49.56
1	3412	3613	5 year	21.09	86.48	88.35	87.85	88.44	0.009825	1.35	16.73	37.71
1	3412	3613	20 Year	30.34	86.48	88.56	88.07	88.63	0.006983	1.3	26.26	80.26
1	3412	3613	50 Year	35.33	86.48	88.63	88.17	88.71	0.006502	1.31	29.87	89.56
1	3412	3613	100 Year	40.47	86.48	88.7	88.45	88.78	0.006198	1.32	33.16	112.37
1	3412	3691	5 year	21.09	86.53	88.63	87.92	88.64	0.001165	0.65	43.29	106.95
1	3412	3691	20 Year	30.34	86.53	88.78	88.3	88.8	0.000953	0.63	59.77	107.4
1	3412	3691	50 Year	35.33	86.53	88.85	88.35	88.86	0.000909	0.64	67.05	107.59
1	3412	3691	100 Year	40.47	86.53	88.92	88.4	88.93	0.000874	0.64	74.09	107.79
1	3412	3836	5 year	21.09	86.92	88.9	88.73	89.2	0.028794	2.43	8.68	9.58
1	3412	3836	20 Year	30.34	86.92	89.03	89.03	89.5	0.042531	3.04	9.99	20.77
1	3412	3836	50 Year	35.33	86.92	89.35	89.35	89.6	0.019206	2.31	17.52	70.09
1	3412	3836	100 Year	40.47	86.92	89.45	89.45	89.67	0.01596	2.23	22.1	86.86
1	3412	4010	5 year	21.09	87.76	90.5	89.78	90.53	0.003501	0.86	26.13	337.61
1	3412	4010	20 Year	30.34	87.76	90.65	90.35	90.69	0.002639	0.83	36.57	352.61
1	3412	4010	50 Year	35.33	87.76	90.67	90.39	90.72	0.003201	0.92	37.87	354.99
1	3412	4010	100 Year	40.47	87.76	90.71	90.44	90.76	0.003461	0.98	40.22	359.28
1	3412	4135	5 year	21.09	88.36	90.81	89.52	90.89	0.002214	1.25	17.18	10.88
1	3412	4135	20 Year	30.34	88.36	90.96	89.78	91.1	0.003581	1.67	18.93	12.44
1	3412	4135	50 Year	35.33	88.36	91.04	89.91	91.21	0.004269	1.86	19.94	13.25
1	3412	4135	100 Year	40.47	88.36	91.1	90.03	91.31	0.005003	2.05	20.88	18.06
1	3412	4136		Bridge								
1	3412	4141	5 year	21.09	88.36	90.82	89.52	90.9	0.002156	1.24	17.36	11.05
1	3412	4141	20 Year	30.34	88.36	90.98	89.78	91.12	0.003422	1.64	19.28	12.72
1	3412	4141	50 Year	35.33	88.36	91.07	89.91	91.23	0.004038	1.83	20.4	13.61
1	3412	4141	100 Year	40.47	88.36	91.15	90.03	91.34	0.004677	2.01	21.47	34.21
1	3412	4220	5 year	21.09	88.77	91.1	90.02	91.13	0.003747	0.78	27.25	215.67
1	3412	4220	20 Year	30.34	88.77	91.36	90.28	91.4	0.003406	0.86	36.63	264.1
1	3412	4220	50 Year	35.33	88.77	91.48	90.39	91.52	0.003019	0.86	43.02	273.41
1	3412	4220	100 Year	40.47	88.77	91.59	90.49	91.63	0.00269	0.85	49.44	284.25
1	3412	4266	5 year	21.09	89.34	91.41	90.44	91.43	0.001758	0.67	33.45	126.94
1	3412	4266	20 Year	30.34	89.34	91.65	90.62	91.67	0.001605	0.72	45.17	166.52
1	3412	4266	50 Year	35.33	89.34	91.75	90.72	91.78	0.001608	0.76	51.29	204.53
1	3412	4266	100 Year	40.47	89.34	91.84	90.81	91.87	0.001552	0.77	57.12	224.01
1	3412	4535	5 year	21.09	90.13	92.12	91.16	92.23	0.005705	1.5	14.1	7.55
1	3412	4535	20 Year	30.34	90.13	92.36	91.42	92.54	0.008359	1.91	15.91	7.6
1	3412	4535	50 Year	35.33	90.13	92.47	91.55	92.7	0.009728	2.1	16.79	7.63
1	3412	4535	100 Year	40.47	90.13	92.55	91.68	92.82	0.011642	2.33	17.35	25.82
1	3412	4540		Bridge								
1	3412	4545	5 year	21.09	90.13	92.18	91.16	92.29	0.0052	1.45	14.56	7.56
1	3412	4545	20 Year	30.34	90.13	92.45	91.42	92.62	0.007393	1.83	16.61	7.62
1	3412	4545	50 Year	35.33	90.13	92.58	91.55	92.79	0.008457	2	17.64	43.35
1	3412	4545	100 Year	40.47	90.13	92.68	91.68	92.93	0.009868	2.2	18.4	87.64
1	3412	4780	5 year	21.09	91.5	93.49	92.8	93.61	0.00664	1.53	13.79	78.48
1	3412	4780	20 Year	30.34	91.5	93.98	93.06	94.06	0.005592	1.36	26.37	173.94
1	3412	4780	50 Year	35.33	91.5	94	93.18	94.01	0.000375	0.36	99.4	179.68
1	3412	4780	100 Year	40.47	91.5	93.3	93.3	93.89	0.037028	3.41	11.88	58.82

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1	3412	4785		Culvert								
1	3412	4790	5 year	21.09	91.5	93.84	92.8	93.91	0.004653	1.14	18.98	137.6
1	3412	4790	20 Year	30.34	91.5	94.08	93.06	94.13	0.003251	1.09	35.21	189.44
1	3412	4790	50 Year	35.33	91.5	94.13	93.18	94.18	0.003451	1.15	39.1	189.44
1	3412	4790	100 Year	40.47	91.5	93.94	93.3	94.12	0.011538	1.91	24.1	166.08
1	3412	5058	5 year	21.09	92.71	94.7		94.73	0.002016	0.75	31.79	77.16
1	3412	5058	20 Year	30.34	92.71	94.84		94.87	0.002178	0.83	44.56	104.39
1	3412	5058	50 Year	35.33	92.71	94.91		94.94	0.002164	0.84	51.22	111.41
1	3412	5058	100 Year	40.47	92.71	95.03		95.05	0.001547	0.75	66.08	125.67
1	3412	5519	5 year	21.09	94.81	96.41	95.96	96.56	0.010335	1.71	12.35	10.3
1	3412	5519	20 Year	30.34	94.81	96.68	96.17	96.88	0.011612	2.01	15.08	10.3
1	3412	5519	50 Year	35.33	94.81	96.77	96.28	97.02	0.013072	2.2	16.04	10.3
1	3412	5519	100 Year	40.47	94.81	96.59	96.38	97	0.025038	2.86	14.16	10.3
1	3412	5524		Culvert								
1	3412	5529	5 year	21.09	94.81	96.46	95.97	96.6	0.009091	1.64	12.87	10.3
1	3412	5529	20 Year	30.34	94.81	96.77	96.17	96.95	0.009577	1.89	16.08	10.3
1	3412	5529	50 Year	35.33	94.81	96.91	96.27	97.11	0.010181	2.03	17.44	10.3
1	3412	5529	100 Year	40.47	94.81	96.83	96.38	97.13	0.015338	2.43	16.65	10.3
1	3412	5836	5 year	21.09	96.67	99.12	98.6	99.26	0.008265	1.8	15.16	47.97
1	3412	5836	20 Year	30.34	96.67	99.29	99.21	99.4	0.006591	1.72	24.51	60.97
1	3412	5836	50 Year	35.33	96.67	99.37	99.26	99.46	0.005835	1.67	29.45	65.56
1	3412	5836	100 Year	40.47	96.67	99.46	99.31	99.54	0.004663	1.56	35.97	72.65
1	3412	5840		Culvert								
1	3412	5846	5 year	21.09	96.67	99.22	98.6	99.3	0.004526	1.39	20.82	56.74
1	3412	5846	20 Year	30.34	96.67	99.36	99.21	99.44	0.004386	1.44	29.21	65.35
1	3412	5846	50 Year	35.33	96.67	99.42	99.26	99.5	0.00427	1.47	33.42	69.87
1	3412	5846	100 Year	40.47	96.67	99.5	99.31	99.57	0.003867	1.44	38.75	75.57
1	3412	5904	5 year	21.09	97	99.39	98.57	99.42	0.00104	0.87	29.94	188.65
1	3412	5904	20 Year	30.34	97	99.53	98.73	99.57	0.001355	1.04	35.73	194.63
1	3412	5904	50 Year	35.33	97	99.59	98.81	99.64	0.001511	1.13	38.34	197.32
1	3412	5904	100 Year	40.47	97	99.65	98.89	99.71	0.001641	1.2	40.99	200.03
1	3412	6338	5 year	21.09	98.71	100.37	100.37	100.75	0.018991	2.9	8.53	12.27
1	3412	6338	20 Year	30.34	98.71	100.68	100.61	101.04	0.014065	2.93	12.87	15.53
1	3412	6338	50 Year	35.33	98.71	100.83	100.72	101.17	0.012463	2.93	15.25	17.05
1	3412	6338	100 Year	40.47	98.71	100.95	100.82	101.3	0.011529	2.97	17.52	18.39
2	157	156.55	5 year	9.02	86.97	87.73		87.74	0.003953	0.55	20.15	83.23
2	157	156.55	20 Year	12.64	86.97	87.9		87.9	0.00181	0.44	37.95	118.77
2	157	156.55	50 Year	14.61	86.97	87.96		87.97	0.00139	0.41	45.83	122.34
2	157	156.55	100 Year	16.8	86.97	88.02		88.02	0.001235	0.4	52.38	125.25
2	157	260.99	5 year	9.02	87.78	88.09	87.93	88.1	0.003175	0.32	27.78	124.47
2	157	260.99	20 Year	12.64	87.78	88.15	87.96	88.15	0.00314	0.35	34.73	129.48
2	157	260.99	50 Year	14.61	87.78	88.17	87.98	88.18	0.003127	0.37	38.23	132.01
2	157	260.99	100 Year	16.8	87.78	88.21	87.99	88.21	0.002973	0.38	42.58	135.09
2	537	537.21	5 year	2.34	89.39	89.46	89.46	89.48	0.048859	0.32	4.18	106.98
2	537	537.21	20 Year	3.44	89.39	89.47	89.47	89.5	0.061656	0.41	5.02	112.25
2	537	537.21	50 Year	4.06	89.39	89.48	89.48	89.51	0.053941	0.43	5.9	117.83
2	537	537.21	100 Year	4.68	89.39	89.48	89.48	89.51	0.057699	0.47	6.36	120.67
2	537	721.8	5 year	2.34	91.65	91.86	91.76	91.87	0.005865	0.35	6.73	212.25
2	537	721.8	20 Year	3.44	91.65	91.9	91.79	91.91	0.005511	0.39	8.94	215.95
2	537	721.8	50 Year	4.06	91.65	91.92	91.8	91.93	0.005773	0.42	9.85	217.49
2	537	721.8	100 Year	4.68	91.65	91.93	91.81	91.94	0.005676	0.44	10.91	219.28
2	537	925.54	5 year	2.34	94.24	94.37	94.36	94.39	0.041755	0.66	3.82	57.25
2	537	925.54	20 Year	3.44	94.24	94.39	94.38	94.42	0.047289	0.78	4.93	72.75
2	537	925.54	50 Year	4.06	94.24	94.4	94.4	94.43	0.041746	0.78	5.89	79.26
2	537	925.54	100 Year	4.68	94.24	94.41	94.41	94.44	0.042996	0.82	6.49	82.49

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
2	537	1115.38	5 year	2.34	96.66	96.84	96.77	96.84	0.006186	0.3	6.54	57.1
2	537	1115.38	20 Year	3.44	96.66	96.87	96.79	96.88	0.005921	0.34	8.59	61.46
2	537	1115.38	50 Year	4.06	96.66	96.88	96.79	96.89	0.006185	0.37	9.45	62.79
2	537	1115.38	100 Year	4.68	96.66	96.9	96.81	96.91	0.006131	0.39	10.43	64.51
2	537	1335.64	5 year	2.34	98.54	98.74	98.68	98.75	0.012918	0.53	4.9	44.04
2	537	1335.64	20 Year	3.44	98.54	98.77		98.78	0.013617	0.6	6.29	48.1
2	537	1335.64	50 Year	4.06	98.54	98.78		98.8	0.012948	0.62	7.18	50.37
2	537	1335.64	100 Year	4.68	98.54	98.8		98.82	0.013033	0.64	7.91	52.02
2	537	1538.74	5 year	2.34	100.68	100.89		100.9	0.008908	0.44	5.19	35.06
2	537	1538.74	20 Year	3.44	100.68	100.94		100.95	0.008588	0.5	6.81	38.43
2	537	1538.74	50 Year	4.06	100.68	100.95		100.97	0.00893	0.53	7.52	39.75
2	537	1538.74	100 Year	4.68	100.68	100.97		100.99	0.008938	0.56	8.27	41.04
2	537	1755.04	5 year	2.34	103.6	103.91	103.82	103.95	0.02527	0.96	2.44	9.4
2	537	1755.04	20 Year	3.44	103.6	103.97	103.88	104.03	0.027648	1.15	3.03	9.94
2	537	1755.04	50 Year	4.06	103.6	104.01	103.91	104.08	0.026332	1.21	3.43	10.28
2	537	1755.04	100 Year	4.68	103.6	104.04	103.94	104.12	0.026728	1.28	3.74	10.52
2	537	1940.92	5 year	2.34	107.47	107.67		107.7	0.016513	0.63	3.12	16.43
2	537	1940.92	20 Year	3.44	107.47	107.73		107.77	0.015268	0.72	4.16	18.02
2	537	1940.92	50 Year	4.06	107.47	107.76		107.8	0.015661	0.78	4.64	19.08
2	537	1940.92	100 Year	4.68	107.47	107.79		107.83	0.015417	0.82	5.17	20.18
2	537	2128.69	5 year	2.34	111.8	111.98		112.01	0.033796	0.78	2.82	22.49
2	537	2128.69	20 Year	3.44	111.8	112.01		112.05	0.037702	0.93	3.54	24.35
2	537	2128.69	50 Year	4.06	111.8	112.03		112.08	0.036192	0.97	4.02	25.57
2	537	2128.69	100 Year	4.68	111.8	112.04		112.1	0.036666	1.02	4.41	26.39
2	537	2284.88	5 year	2.34	115.11	115.4	115.33	115.42	0.015259	0.69	3.75	25.72
2	537	2284.88	20 Year	3.44	115.11	115.44	115.37	115.47	0.014248	0.75	5.05	29.15
2	537	2284.88	50 Year	4.06	115.11	115.46	115.4	115.49	0.014586	0.8	5.63	30.57
2	537	2284.88	100 Year	4.68	115.11	115.48	115.4	115.51	0.014496	0.83	6.24	32
2	537	2443.45	5 year	2.34	119.98	120.14	120.14	120.18	0.071007	1.06	2.48	30.29
2	537	2443.45	20 Year	3.44	119.98	120.18	120.18	120.22	0.044697	0.99	3.81	35.76
2	537	2443.45	50 Year	4.06	119.98	120.19	120.17	120.24	0.041743	1.01	4.39	37.95
2	537	2443.45	100 Year	4.68	119.98	120.19	120.19	120.25	0.054118	1.15	4.43	38.09
3	126	125.72	5 year	6.64	88.72	89	89	89.04	0.053657	1.04	7.64	87.43
3	126	125.72	20 Year	9.17	88.72	89.02	89.02	89.07	0.043567	1.04	10.39	98.8
3	126	125.72	50 Year	10.65	88.72	89.03	89.03	89.08	0.046183	1.1	11.3	101.59
3	126	125.72	100 Year	12.33	88.72	89.04	89.04	89.1	0.05484	1.22	11.79	103.05
3	126	289.48	5 year	6.64	89.32	90.1	89.83	90.11	0.002408	0.47	14.4	40.47
3	126	289.48	20 Year	9.17	89.32	90.18	89.87	90.2	0.002699	0.55	18.29	53.78
3	126	289.48	50 Year	10.65	89.32	90.24	89.9	90.25	0.002759	0.59	21.47	65.95
3	126	289.48	100 Year	12.33	89.32	90.28	89.93	90.3	0.002738	0.61	24.69	75.62
3	126	505.92	5 year	6.64	91.65	91.92	91.92	92.05	0.063549	1.5	4.2	16
3	126	505.92	20 Year	9.17	91.65	91.98	91.98	92.14	0.060322	1.67	5.2	16
3	126	505.92	50 Year	10.65	91.65	92.01	92.01	92.19	0.058194	1.76	5.75	16
3	126	505.92	100 Year	12.33	91.65	92.05	92.05	92.25	0.056177	1.85	6.36	16
3	126	515		Bridge								
3	126	524.98	5 year	6.64	91.71	92.25	91.98	92.28	0.006327	0.75	8.49	16
3	126	524.98	20 Year	9.17	91.71	92.34	92.04	92.39	0.006901	0.88	10.08	16
3	126	524.98	50 Year	10.65	91.71	92.4	92.07	92.45	0.007172	0.94	10.93	16
3	126	524.98	100 Year	12.33	91.71	92.45	92.11	92.51	0.007477	1.01	11.81	16
3	126	606.02	5 year	6.64	92.58	92.84		92.85	0.007696	0.41	15.56	115
3	126	606.02	20 Year	9.17	92.58	92.89		92.9	0.005513	0.4	20.99	115
3	126	606.02	50 Year	10.65	92.58	92.91		92.93	0.004737	0.4	24.05	115
3	126	606.02	100 Year	12.33	92.58	92.95	92.81	92.96	0.004048	0.4	27.54	115
3	126	770.49	5 year	6.64	94.28	94.54		94.58	0.015152	0.45	8.5	46.47
3	126	770.49	20 Year	9.17	94.28	94.55	94.52	94.61	0.026051	0.61	8.81	46.98
3	126	770.49	50 Year	10.65	94.28	94.55	94.54	94.63	0.036871	0.72	8.66	46.74
3	126	770.49	100 Year	12.33	94.28	94.56	94.56	94.66	0.039974	0.8	9.33	47.81
3	126	935.46	5 year	6.64	96.78	97.17	97.06	97.22	0.016747	0.95	6.65	40.73
3	126	935.46	20 Year	9.17	96.78	97.28	97.12	97.34	0.011388	0.94	9.17	51.7
3	126	935.46	50 Year	10.65	96.78	97.35	97.14	97.4	0.009508	0.93	10.64	54.87
3	126	935.46	100 Year	12.33	96.78	97.4	97.18	97.46	0.009267	0.97	11.73	57.26
3	126	1082.88	5 year	6.64	98.15	98.85	98.56	98.89	0.008115	0.89	7.51	58.65
3	126	1082.88	20 Year	9.17	98.15	98.91	98.63	98.98	0.010836	1.1	8.4	59.46
3	126	1082.88	50 Year	10.65	98.15	98.94	98.68	99.02	0.012597	1.22	8.81	59.81
3	126	1082.88	100 Year	12.33	98.15	98.99	98.72	99.08	0.013169	1.31	9.53	60.45

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
3	126	1235.08	5 year	6.64	100.88	101.2	101.18	101.27	0.041511	1.28	5.63	29.52
3	126	1235.08	20 Year	9.17	100.88	101.29	101.22	101.35	0.024264	1.17	8.54	35.54
3	126	1235.08	50 Year	10.65	100.88	101.33	101.25	101.39	0.019765	1.14	10.22	38.57
3	126	1235.08	100 Year	12.33	100.88	101.37	101.27	101.42	0.018309	1.15	11.63	40.59
4	97	97.48	5 year	39.92	77.82	80.28	79.61	80.41	0.006944	1.63	25.29	19.03
4	97	97.48	20 Year	56.71	77.82	80.84	79.86	80.96	0.004599	1.61	37.24	26.02
4	97	97.48	50 Year	65.95	77.82	81.1	79.99	81.22	0.004177	1.64	44.86	128.79
4	97	97.48	100 Year	75.31	77.82	81.15	80.09	81.24	0.003618	1.56	73.66	216.5
4	97	466.3	5 year	39.92	78.92	81.67		81.76	0.002262	1.35	31.5	36.11
4	97	466.3	20 Year	56.71	78.92	81.98		82.08	0.002204	1.45	47.32	59.59
4	97	466.3	50 Year	65.95	78.92	82.15		82.24	0.002046	1.45	58.06	75.77
4	97	466.3	100 Year	75.31	78.92	82.19		82.29	0.002386	1.59	61.3	77.88
4	97	622.77	5 year	39.92	79.99	82.29	81.9	82.42	0.010081	1.66	25.04	25.45
4	97	622.77	20 Year	56.71	79.99	82.57	82.09	82.73	0.009406	1.82	32.28	27.74
4	97	622.77	50 Year	65.95	79.99	82.68	82.19	82.86	0.009494	1.92	35.55	28.59
4	97	622.77	100 Year	75.31	79.99	82.79	82.28	82.99	0.009602	2.01	38.67	29.38
4	97	793.4	5 year	39.92	80.31	83.21	82.1	83.25	0.002927	0.92	43.35	34.46
4	97	793.4	20 Year	56.71	80.31	83.5	82.31	83.56	0.003034	1.06	54.93	86.44
4	97	793.4	50 Year	65.95	80.31	83.64	82.41	83.7	0.003044	1.12	62.29	99.97
4	97	793.4	100 Year	75.31	80.31	83.76	82.5	83.82	0.003016	1.17	69.72	104.66
4	998	997.99	5 year	35.38	81.08	83.91	83.04	84	0.004688	1.43	28.06	28.66
4	998	997.99	20 Year	50.35	81.08	84.21	83.34	84.32	0.004514	1.55	37.01	30.88
4	998	997.99	50 Year	58.51	81.08	84.34	83.48	84.46	0.004521	1.62	41.19	31.9
4	998	997.99	100 Year	66.85	81.08	84.46	83.78	84.58	0.004592	1.69	45.03	32.82
4	998	1190.83	5 year	35.38	81.6	84.62	83.33	84.66	0.002558	0.87	40.85	30.37
4	998	1190.83	20 Year	50.35	81.6	84.93	83.62	84.98	0.002762	0.99	50.87	33.57
4	998	1190.83	50 Year	58.51	81.6	85.07	83.75	85.13	0.002793	1.06	55.64	34.7
4	998	1190.83	100 Year	66.85	81.6	85.2	83.87	85.26	0.002836	1.12	60.23	37.41
4	998	1378.46	5 year	35.38	82.31	85.15	84.15	85.21	0.003626	1.12	31.87	51.27
4	998	1378.46	20 Year	50.35	82.31	85.48	84.39	85.57	0.003726	1.29	40.24	85.17
4	998	1378.46	50 Year	58.51	82.31	85.63	84.5	85.72	0.003759	1.36	45.79	98.14
4	998	1378.46	100 Year	66.85	82.31	85.76	84.61	85.86	0.003741	1.42	51.54	109.83
4	998	1385		Bridge								
4	998	1395.18	5 year	35.38	82.31	85.24	84.15	85.3	0.002954	1.06	33.9	58.69
4	998	1395.18	20 Year	50.35	82.31	85.58	84.39	85.66	0.003024	1.21	43.98	94.12
4	998	1395.18	50 Year	58.51	82.31	85.73	84.5	85.81	0.003022	1.27	50.2	107.13
4	998	1395.18	100 Year	66.85	82.31	85.87	84.61	85.95	0.002989	1.32	56.62	118.88
4	998	1448.28	5 year	35.38	82.71	85.41	84.79	85.59	0.009192	1.89	19.77	38.65
4	998	1448.28	20 Year	50.35	82.71	85.74	85.1	85.96	0.009315	2.14	25.27	61.29
4	998	1448.28	50 Year	58.51	82.71	85.88	85.26	86.12	0.009657	2.28	27.77	71.14
4	998	1448.28	100 Year	66.85	82.71	86.01	85.39	86.27	0.01004	2.41	30.14	78.44
4	998	1584.49	5 year	35.38	83.04	86.11	84.87	86.16	0.002148	1.06	38.79	35.27
4	998	1584.49	20 Year	50.35	83.04	86.47	85.26	86.52	0.002031	1.14	52.91	44.51
4	998	1584.49	50 Year	58.51	83.04	86.62	85.44	86.68	0.001963	1.16	60.04	47.09
4	998	1584.49	100 Year	66.85	83.04	86.77	85.57	86.83	0.001911	1.19	67.76	72.36
4	998	1751.07	5 year	35.38	84.14	86.55	85.55	86.62	0.003652	1.32	31.37	33.58
4	998	1751.07	20 Year	50.35	84.14	86.87	85.84	86.95	0.003354	1.4	43.01	39.01
4	998	1751.07	50 Year	58.51	84.14	87.01	86.08	87.03	0.000928	0.76	108.02	130.47
4	998	1751.07	100 Year	66.85	84.14	87.04	86.28	87.06	0.001098	0.84	111.7	130.79
4	998	1925.64	5 year	35.38	84.61	87.32	86.58	87.46	0.006507	1.67	22.92	19.06
4	998	1925.64	20 Year	50.35	84.61	87.61	86.87	87.79	0.007461	1.97	29.73	31.14
4	998	1925.64	50 Year	58.51	84.61	87.14	87	87.61	0.02634	3.14	19.73	16.17
4	998	1925.64	100 Year	66.85	84.61	87.18	87.13	87.76	0.031708	3.5	20.32	16.57
4	998	2128.51	5 year	35.38	85.2	88.35	87.53	88.42	0.003854	1.35	31.98	35.56
4	998	2128.51	20 Year	50.35	85.2	88.66	87.92	88.73	0.003415	1.39	43.58	39.86
4	998	2128.51	50 Year	58.51	85.2	88.85	88.14	88.92	0.002921	1.36	51.47	42.5
4	998	2128.51	100 Year	66.85	85.2	89	88.21	89.07	0.002753	1.37	57.91	44.55

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4	998	2130		Lat Struct								
4	998	2208.09	5 year	35.38	85.82	88.73	88.11	88.86	0.007898	1.66	22.59	19.51
4	998	2208.09	20 Year	50.35	85.82	88.99	88.4	89.17	0.008662	1.93	27.96	21.27
4	998	2208.09	50 Year	58.51	85.82	89.13	88.53	89.32	0.008712	2.03	31	22.3
4	998	2208.09	100 Year	66.85	85.82	89.26	88.65	89.47	0.008865	2.13	33.82	23.19
4	998	2351.97	5 year	35.38	86.17	89.52		89.58	0.003383	1.21	33.75	33.27
4	998	2351.97	20 Year	50.35	86.17	89.81		89.88	0.003173	1.28	43.84	35.35
4	998	2351.97	50 Year	58.51	86.17	89.95		90.02	0.003098	1.32	48.87	36.3
4	998	2351.97	100 Year	66.85	86.17	90.08		90.16	0.003038	1.35	53.78	37.2
4	998	2609.13	5 year	35.38	88.13	90.23		90.27	0.00223	0.89	42.34	43.92
4	998	2609.13	20 Year	50.35	88.13	90.51		90.55	0.002255	1	55.74	53.21
4	998	2609.13	50 Year	58.51	88.13	90.64		90.68	0.002221	1.04	62.77	55.03
4	998	2609.13	100 Year	66.85	88.13	90.76		90.81	0.002176	1.08	69.58	56.03
4	998	2821.02	5 year	35.38	88.76	91.12	90.88	91.3	0.015242	2.02	20.02	28.11
4	998	2821.02	20 Year	50.35	88.76	91.36		91.55	0.013153	2.09	26.77	29.34
4	998	2821.02	50 Year	58.51	88.76	91.46		91.66	0.012923	2.16	29.75	29.88
4	998	2821.02	100 Year	66.85	88.76	91.55		91.77	0.012653	2.22	32.7	30.39
4	998	3060	5 year	35.38	89.92	92.96		93.04	0.004296	1.33	28.42	22.39
4	998	3060	20 Year	50.35	89.92	93.22		93.34	0.004969	1.56	34.65	24.68
4	998	3060	50 Year	58.51	89.92	93.36		93.48	0.00519	1.67	37.96	25.82
4	998	3060	100 Year	66.85	89.92	93.48		93.62	0.005398	1.76	41.17	26.88
4	998	3070		Bridge								
4	998	3076.33	5 year	35.38	89.92	93.04	92.08	93.12	0.003571	1.25	30.34	23.14
4	998	3076.33	20 Year	50.35	89.92	93.34	92.35	93.44	0.003944	1.45	37.62	25.7
4	998	3076.33	50 Year	58.51	89.92	93.49	92.46	93.6	0.004043	1.53	41.5	26.99
4	998	3076.33	100 Year	66.85	89.92	93.63	92.59	93.75	0.004113	1.61	45.37	28.22
4	998	3280.72	5 year	35.38	91.48	93.58		93.61	0.001773	0.7	48.43	48.02
4	998	3280.72	20 Year	50.35	91.48	93.88		93.91	0.001538	0.75	62.99	49.88
4	998	3280.72	50 Year	58.51	91.48	94.03		94.06	0.001463	0.78	70.4	51.74
4	998	3280.72	100 Year	66.85	91.48	94.17		94.2	0.001405	0.8	77.68	53.02
4	998	3747.08	5 year	35.38	93.91	95.26		95.43	0.014671	1.8	19.74	19.56
4	998	3747.08	20 Year	50.35	93.91	95.42		95.67	0.01865	2.23	22.9	20.51
4	998	3747.08	50 Year	58.51	93.91	95.5		95.79	0.020286	2.42	24.56	21.04
4	998	3747.08	100 Year	66.85	93.91	95.58		95.92	0.021689	2.6	26.22	21.58
4	998	3953.34	5 year	35.38	95.37	97.77	97.21	97.89	0.009879	1.55	22.91	20.54
4	998	3953.34	20 Year	50.35	95.37	98.09	97.44	98.24	0.008793	1.72	29.88	22.83
4	998	3953.34	50 Year	58.51	95.37	98.24	97.54	98.4	0.008503	1.8	33.37	23.84
4	998	3953.34	100 Year	66.85	95.37	98.38	97.66	98.55	0.008291	1.87	36.78	24.83
4	998	4117.06	5 year	35.38	96.57	98.57	97.48	98.63	0.002554	1.02	35.64	24.48
4	998	4117.06	20 Year	50.35	96.57	98.91	97.7	98.98	0.002718	1.18	44.25	26.89
4	998	4117.06	50 Year	58.51	96.57	99.07	97.8	99.15	0.002788	1.26	48.58	27.99
4	998	4117.06	100 Year	66.85	96.57	99.22	97.9	99.3	0.00285	1.33	52.83	29.04
4	4350	4350.2	5 year	10.99	98.54	99.64	99.64	99.92	0.123731	2.37	4.64	8.23
4	4350	4350.2	20 Year	15.8	98.54	99.81	99.81	100.15	0.112043	2.58	6.17	9.43
4	4350	4350.2	50 Year	18.52	98.54	99.9	99.9	100.26	0.107375	2.67	7.01	10.03
4	4350	4350.2	100 Year	21.31	98.54	100.1		100.38	0.06538	2.38	9.15	11.52
4	4350	4568.03	5 year	10.99	102.34	103.83		103.87	0.00714	0.93	12.92	16.87
4	4350	4568.03	20 Year	15.8	102.34	104.03		104.08	0.007353	1.05	16.54	18.93
4	4350	4568.03	50 Year	18.52	102.34	104.13		104.18	0.00745	1.1	18.42	19.84
4	4350	4568.03	100 Year	21.31	102.34	104.18		104.24	0.008567	1.21	19.36	20.28
4	4350	4707.35	5 year	10.99	104.46	105.68	105.5	105.83	0.037393	1.78	6.64	10.54
4	4350	4707.35	20 Year	15.8	104.46	105.87		106.05	0.035043	1.95	8.78	12.04
4	4350	4707.35	50 Year	18.52	104.46	105.96		106.15	0.034122	2.03	9.93	12.79
4	4350	4707.35	100 Year	21.31	104.46	106.09		106.27	0.02883	2	11.67	13.91
4	4350	4930.62	5 year	10.99	105.69	107.56	106.78	107.59	0.003582	0.79	15.49	16.83
4	4350	4930.62	20 Year	15.8	105.69	107.79	106.94	107.82	0.003768	0.89	19.45	17.91
4	4350	4930.62	50 Year	18.52	105.69	107.9	107.05	107.94	0.003852	0.93	21.5	18.45
4	4350	4930.62	100 Year	21.31	105.69	107.99	107.12	108.04	0.004052	0.99	23.24	18.89

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
4	5123	5123.42	5 year	8.21	107.82	108.97		109.11	0.055179	1.69	4.91	8.56
4	5123	5123.42	20 Year	11.8	107.82	109.18		109.34	0.041284	1.77	6.89	10.14
4	5123	5123.42	50 Year	13.88	107.82	109.29		109.45	0.036713	1.8	8.02	10.94
4	5123	5123.42	100 Year	15.99	107.82	109.4		109.56	0.031722	1.81	9.32	11.77
4	5123	5276.37	5 year	8.21	109.47	111.43	110.65	111.47	0.007069	0.91	9.28	9.38
4	5123	5276.37	20 Year	11.8	109.47	111.65	110.83	111.71	0.008007	1.08	11.42	10.42
4	5123	5276.37	50 Year	13.88	109.47	111.75	110.92	111.82	0.008489	1.17	12.53	10.92
4	5123	5276.37	100 Year	15.99	109.47	111.84	111	111.92	0.009063	1.25	13.52	11.34
4	5123	5408.69	5 year	8.21	112.73	113.85	113.85	114.15	0.13075	2.4	3.43	6.12
4	5123	5408.69	20 Year	11.8	112.73	114.05	114.03	114.37	0.104125	2.51	4.75	7.22
4	5123	5408.69	50 Year	13.88	112.73	114.17	114.12	114.49	0.084209	2.5	5.67	7.89
4	5123	5408.69	100 Year	15.99	112.73	114.28	114.2	114.6	0.072238	2.51	6.57	8.5
4	5123	5539.2	5 year	8.21	116.63	118.02		118.07	0.012875	1.05	8.2	11.79
4	5123	5539.2	20 Year	11.8	116.63	118.19		118.26	0.013687	1.21	10.34	13.25
4	5123	5539.2	50 Year	13.88	116.63	118.26		118.34	0.014704	1.31	11.31	13.86
4	5123	5539.2	100 Year	15.99	116.63	118.33		118.42	0.015576	1.4	12.25	14.42
4	5123	5653.04	5 year	8.21	116.67	118.68		118.7	0.003047	0.65	13.27	13.22
4	5123	5653.04	20 Year	11.8	116.67	118.91		118.94	0.003349	0.76	16.57	14.79
4	5123	5653.04	50 Year	13.88	116.67	119.03		119.06	0.003495	0.81	18.31	15.58
4	5123	5653.04	100 Year	15.99	116.67	119.13		119.17	0.003619	0.86	19.99	16.25
4	5123	5785.71	5 year	8.21	118.32	119.67		119.85	0.070456	1.92	4.28	6.38
4	5123	5785.71	20 Year	11.8	118.32	119.92		120.12	0.051107	1.95	6.09	7.61
4	5123	5785.71	50 Year	13.88	118.32	120.04		120.25	0.045525	2	7.03	8.19
4	5123	5785.71	100 Year	15.99	118.32	120.15		120.37	0.041793	2.06	7.96	8.72
4	5123	5901.83	5 year	8.21	119.31	121.37	120.51	121.41	0.005398	0.9	9.79	9.49
4	5123	5901.83	20 Year	11.8	119.31	121.62	120.69	121.67	0.005914	1.04	12.26	10.6
4	5123	5901.83	50 Year	13.88	119.31	121.74	120.79	121.79	0.00616	1.11	13.57	11.15
4	5123	5901.83	100 Year	15.99	119.31	121.85	120.88	121.91	0.00636	1.17	14.84	11.66
4	5123	6020.9	5 year	8.21	122.76	123.8	123.8	124.06	0.091713	2.36	3.71	7.22
4	5123	6020.9	20 Year	11.8	122.76	123.96	123.96	124.26	0.084408	2.58	4.95	8.34
4	5123	6020.9	50 Year	13.88	122.76	124.04	124.04	124.36	0.079731	2.66	5.67	8.94
4	5123	6020.9	100 Year	15.99	122.76	124.12	124.12	124.45	0.076295	2.74	6.37	9.47
4	5123	6113.46	5 year	8.21	123.37	125.42	124.52	125.45	0.005758	0.76	10.88	10.64
4	5123	6113.46	20 Year	11.8	123.37	125.65		125.69	0.006128	0.88	13.54	11.87
4	5123	6113.46	50 Year	13.88	123.37	125.77		125.81	0.006333	0.95	14.91	12.46
4	5123	6113.46	100 Year	15.99	123.37	125.87		125.92	0.00652	1.01	16.23	12.99
4	5123	6211.75	5 year	8.21	125.97	126.72	126.72	126.86	0.071245	1.76	5.37	18.89
4	5123	6211.75	20 Year	11.8	125.97	126.86	126.82	126.97	0.047482	1.67	8.23	23.1
4	5123	6211.75	50 Year	13.88	125.97	126.93	126.86	127.03	0.037749	1.59	9.94	23.94
4	5123	6211.75	100 Year	15.99	125.97	127.01	126.89	127.1	0.03173	1.56	11.91	27.35
5	35	34.83	5 year	23.85	97.54	99	99	99.36	0.057489	2.67	8.94	12.64
5	35	34.83	20 Year	33.94	97.54	99.21	99.21	99.63	0.056263	2.87	11.84	14.82
5	35	34.83	50 Year	39.5	97.54	99.53	99.53	99.72	0.023036	2.05	22.57	58.49
5	35	34.83	100 Year	45.23	97.54	99.57	99.57	99.78	0.025176	2.18	24.72	61.6
5	35	139.68	5 year	23.85	98.15	100.06	99.5	100.08	0.00284	0.73	42.46	106.47
5	35	139.68	20 Year	33.94	98.15	100.2	99.86	100.22	0.002343	0.73	57.86	108.67
5	35	139.68	50 Year	39.5	98.15	100.22	99.9	100.24	0.002854	0.81	59.94	108.93
5	35	139.68	100 Year	45.23	98.15	100.27	99.94	100.3	0.002889	0.84	65.25	109.52

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5	287	287.07	5 year	21.98	99.34	100.92		101.09	0.037041	1.86	11.84	20.84
5	287	287.07	20 Year	31.47	99.34	100.98	100.98	101.27	0.055259	2.37	13.28	21.86
5	287	287.07	50 Year	36.68	99.34	101.07	101.05	101.37	0.051004	2.41	15.22	23.03
5	287	287.07	100 Year	42.01	99.34	101.12	101.1	101.45	0.055063	2.58	16.29	23.6
5	287	300		Bridge								
5	287	314.64	5 year	21.98	99.34	101.39	100.76	101.43	0.005523	0.95	23.15	26.77
5	287	314.64	20 Year	31.47	99.34	101.64	100.98	101.69	0.005333	1.04	30.18	29.56
5	287	314.64	50 Year	36.68	99.34	101.76	101.04	101.82	0.005286	1.09	33.76	30.9
5	287	314.64	100 Year	42.01	99.34	101.87	101.1	101.94	0.005194	1.12	37.43	32.22
5	287	584	5 year	21.98	101.6	103.35	102.87	103.45	0.009212	1.43	17.52	32.78
5	287	584	20 Year	31.47	101.6	103.55	103.25	103.65	0.008082	1.49	24.68	48.63
5	287	584	50 Year	36.68	101.6	103.65	103.34	103.74	0.007547	1.51	28.36	51.67
5	287	584	100 Year	42.01	101.6	103.73	103.41	103.83	0.00717	1.53	31.87	55.77
5	883	883.08	5 year	20.6	103.62	105.5		105.55	0.005418	1.15	20.6	32.6
5	883	883.08	20 Year	29.63	103.62	105.65		105.72	0.005963	1.31	25.63	33.15
5	883	883.08	50 Year	34.62	103.62	105.72		105.81	0.006265	1.39	28.04	34.22
5	883	883.08	100 Year	39.71	103.62	105.79		105.88	0.006577	1.47	30.3	35.41
5	883	1137.7	5 year	20.6	105.43	106.96	106.44	107.07	0.007454	1.59	14.53	42.83
5	883	1137.7	20 Year	29.63	105.43	107.19	106.66	107.33	0.007805	1.79	18.47	50.42
5	883	1137.7	50 Year	34.62	105.43	107.31	106.75	107.46	0.00807	1.91	20.6	51.91
5	883	1137.7	100 Year	39.71	105.43	107.42	106.86	107.58	0.00823	2	22.79	56.26
5	883	1287.21	5 year	20.6	106.56	108.48	108.16	108.68	0.01672	2.02	10.61	11.24
5	883	1287.21	20 Year	29.63	106.56	108.74	108.42	108.99	0.016763	2.3	13.67	28.23
5	883	1287.21	50 Year	34.62	106.56	108.87	108.54	109.14	0.01641	2.4	15.37	43.79
5	883	1287.21	100 Year	39.71	106.56	108.98	108.66	109.28	0.016344	2.51	16.97	48.95
5	883	1457.84	5 year	20.6	108.4	110.62		110.78	0.010022	2.07	12.61	16.06
5	883	1457.84	20 Year	29.63	108.4	110.87		111.05	0.009827	2.23	17.23	20.26
5	883	1457.84	50 Year	34.62	108.4	110.98		111.17	0.00975	2.29	19.6	21.96
5	883	1457.84	100 Year	39.71	108.4	111.1		111.29	0.009643	2.36	22.25	24.75
5	883	1561.13	5 year	20.6	111.57	112.38	112.38	112.63	0.039425	2.25	9.39	18.95
5	883	1561.13	20 Year	29.63	111.57	112.53	112.52	112.83	0.036338	2.45	12.2	20.1
5	883	1561.13	50 Year	34.62	111.57	112.6	112.59	112.93	0.035019	2.53	13.67	20.67
5	883	1561.13	100 Year	39.71	111.57	112.67	112.66	113.02	0.033931	2.62	15.11	21.22
5	883	1665.27	5 year	20.6	114.05	114.79		114.87	0.013433	1.32	16.03	27.62
5	883	1665.27	20 Year	29.63	114.05	114.93		115.04	0.013778	1.51	20.13	29.25
5	883	1665.27	50 Year	34.62	114.05	115		115.13	0.014011	1.61	22.17	30.04
5	883	1665.27	100 Year	39.71	114.05	115.07		115.21	0.014112	1.69	24.2	30.82
5	883	1769.01	5 year	20.6	115.52	116.35		116.47	0.017549	1.62	13.09	20.34
5	883	1769.01	20 Year	29.63	115.52	116.51	116.3	116.68	0.01774	1.84	16.54	21.72
5	883	1769.01	50 Year	34.62	115.52	116.59		116.78	0.017785	1.95	18.31	22.4
5	883	1769.01	100 Year	39.71	115.52	116.66		116.87	0.017986	2.05	19.98	23.02
5	883	1859.76	5 year	20.6	116.76	117.97	117.74	118.14	0.018849	1.86	11.71	16.95
5	883	1859.76	20 Year	29.63	116.76	118.15	117.92	118.36	0.018984	2.11	15.24	20.12
5	883	1859.76	50 Year	34.62	116.76	118.23	118.08	118.46	0.019122	2.22	16.92	20.62
5	883	1859.76	100 Year	39.71	116.76	118.31	118.15	118.56	0.019063	2.31	18.6	21.12
5	883	1964.51	5 year	20.6	118.44	119.59	119.26	119.69	0.011906	1.45	14.6	18.51
5	883	1964.51	20 Year	29.63	118.44	119.78	119.42	119.92	0.012043	1.66	18.4	19.66
5	883	1964.51	50 Year	34.62	118.44	119.88	119.5	120.03	0.01205	1.76	20.36	20.23
5	883	1964.51	100 Year	39.71	118.44	119.97	119.57	120.14	0.012152	1.86	22.21	20.75
5	883	2046.72	5 year	20.6	120.51	121.27	121.27	121.56	0.053959	2.4	8.69	15.34
5	883	2046.72	20 Year	29.63	120.51	121.44	121.44	121.8	0.047995	2.66	11.39	16.44
5	883	2046.72	50 Year	34.62	120.51	121.52	121.52	121.91	0.046123	2.79	12.76	16.97
5	883	2046.72	100 Year	39.71	120.51	121.6	121.6	122.02	0.044332	2.9	14.14	17.48
6	136	135.86	5 year	1.18	105.26	105.39	105.39	105.43	0.105406	0.92	1.28	14.94
6	136	135.86	20 Year	1.71	105.26	105.42	105.42	105.47	0.096125	1.04	1.66	15.31
6	136	135.86	50 Year	1.97	105.26	105.43	105.43	105.49	0.091665	1.08	1.84	15.48
6	136	135.86	100 Year	2.28	105.26	105.45	105.45	105.51	0.067712	1.04	2.21	15.83

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6	136	221.44	5 year	1.18	107.34	107.61	107.5	107.62	0.011208	0.5	2.37	12.59
6	136	221.44	20 Year	1.71	107.34	107.66	107.54	107.67	0.011628	0.58	2.98	13.41
6	136	221.44	50 Year	1.97	107.34	107.67	107.56	107.69	0.011888	0.61	3.23	13.69
6	136	221.44	100 Year	2.28	107.34	107.69	107.57	107.71	0.013373	0.67	3.41	13.89
6	136	325.77	5 year	1.18	110.77	110.91	110.91	110.95	0.082353	0.96	1.28	14.17
6	136	325.77	20 Year	1.71	110.77	110.93	110.93	110.99	0.075994	1.06	1.68	15.27
6	136	325.77	50 Year	1.97	110.77	110.94	110.94	111	0.076132	1.12	1.84	15.68
6	136	325.77	100 Year	2.28	110.77	110.96	110.96	111.02	0.072019	1.15	2.07	16.23
6	136	435.55	5 year	1.18	111.67	112.2	111.92	112.22	0.004392	0.57	2.13	5.32
6	136	435.55	20 Year	1.71	111.67	112.3	111.98	112.32	0.004714	0.67	2.67	5.75
6	136	435.55	50 Year	1.97	111.67	112.34	112.01	112.36	0.004854	0.71	2.91	5.93
6	136	435.55	100 Year	2.28	111.67	112.38	112.04	112.41	0.005033	0.76	3.17	6.12
6	136	508.23	5 year	1.18	114.69	115.02	115.02	115.11	0.084308	1.3	0.91	5.5
6	136	508.23	20 Year	1.71	114.69	115.05	115.08	115.18	0.106899	1.62	1.07	6.01
6	136	508.23	50 Year	1.97	114.69	115.08	115.1	115.21	0.087438	1.61	1.26	6.56
6	136	508.23	100 Year	2.28	114.69	115.1	115.13	115.24	0.088088	1.7	1.39	6.91
6	136	620.35	5 year	1.18	122.62	122.86	122.85	122.91	0.058479	1.05	1.19	9.83
6	136	620.35	20 Year	1.71	122.62	122.9	122.9	122.96	0.048492	1.11	1.68	12.35
6	136	620.35	50 Year	1.97	122.62	122.91	122.91	122.98	0.056127	1.22	1.76	12.6
6	136	620.35	100 Year	2.28	122.62	122.92	122.92	123	0.055625	1.28	1.98	13.63
7	128	127.73	5 year	2.25	103.08	103.22	103.22	103.28	0.094286	1.14	1.97	14.8
7	128	127.73	20 Year	3.16	103.08	103.25	103.25	103.33	0.08763	1.27	2.48	15
7	128	127.73	50 Year	3.59	103.08	103.27	103.27	103.36	0.085903	1.33	2.7	15.09
7	128	127.73	100 Year	4.08	103.08	103.28	103.28	103.38	0.087541	1.4	2.91	15.17
7	128	266.37	5 year	2.25	104.55	105.12	104.87	105.13	0.005065	0.57	4.05	10.91
7	128	266.37	20 Year	3.16	104.55	105.2	104.92	105.22	0.005275	0.65	4.98	11.6
7	128	266.37	50 Year	3.59	104.55	105.23	104.95	105.26	0.005356	0.69	5.38	11.89
7	128	266.37	100 Year	4.08	104.55	105.27	104.97	105.3	0.005361	0.72	5.86	12.22
7	128	433.14	5 year	2.25	107.42	107.88	107.88	107.99	0.079868	1.48	1.52	6.79
7	128	433.14	20 Year	3.16	107.42	107.94	107.94	108.07	0.076746	1.59	1.99	7.78
7	128	433.14	50 Year	3.59	107.42	107.97	107.97	108.1	0.07556	1.63	2.21	8.18
7	128	433.14	100 Year	4.08	107.42	108	108	108.14	0.074366	1.68	2.43	8.63
7	128	612.82	5 year	2.25	110.78	111.36	111.15	111.38	0.008188	0.54	4.15	15.73
7	128	612.82	20 Year	3.16	110.78	111.42	111.21	111.44	0.008245	0.61	5.21	17.95
7	128	612.82	50 Year	3.59	110.78	111.45	111.23	111.47	0.008289	0.64	5.69	18.87
7	128	612.82	100 Year	4.08	110.78	111.48	111.26	111.5	0.008275	0.67	6.24	19.69
7	128	680.22	5 year	2.25	115.94	116.23	116.23	116.33	0.080987	1.41	1.6	8
7	128	680.22	20 Year	3.16	115.94	116.29	116.29	116.41	0.074454	1.54	2.06	8.56
7	128	680.22	50 Year	3.59	115.94	116.31	116.31	116.44	0.073991	1.61	2.25	8.78
7	128	680.22	100 Year	4.08	115.94	116.34	116.34	116.48	0.070742	1.66	2.49	9.05
7	128	763.09	5 year	2.25	115.84	116.44	115.97	116.44	0.000325	0.16	13.96	69.33
7	128	763.09	20 Year	3.16	115.84	116.52	116	116.53	0.000364	0.19	17.21	82.75
7	128	763.09	50 Year	3.59	115.84	116.56	116	116.56	0.000376	0.2	18.72	84.76
7	128	763.09	100 Year	4.08	115.84	116.6	116.02	116.6	0.000387	0.22	20.34	87.04

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
7	128	946.58	5 year	2.25	121.41	121.77	121.77	121.84	0.048164	1.26	2.17	16.78
7	128	946.58	20 Year	3.16	121.41	121.81	121.81	121.89	0.047887	1.39	2.92	21.08
7	128	946.58	50 Year	3.59	121.41	121.83	121.83	121.9	0.042652	1.37	3.42	23.39
7	128	946.58	100 Year	4.08	121.41	121.85	121.85	121.92	0.042412	1.41	3.79	24.34
7	128	1041.45	5 year	2.25	125.31	125.59	125.54	125.64	0.033798	0.95	2.42	12.57
7	128	1041.45	20 Year	3.16	125.31	125.64	125.58	125.69	0.034262	1.08	3	13.4
7	128	1041.45	50 Year	3.59	125.31	125.65	125.6	125.72	0.037898	1.17	3.16	13.63
7	128	1041.45	100 Year	4.08	125.31	125.67	125.62	125.74	0.038436	1.23	3.42	14.04
7	128	1154.14	5 year	2.25	131.11	131.64	131.63	131.77	0.07632	1.61	1.4	5.29
7	128	1154.14	20 Year	3.16	131.11	131.71	131.71	131.86	0.075852	1.74	1.81	6.03
7	128	1154.14	50 Year	3.59	131.11	131.74	131.74	131.9	0.074601	1.79	2.01	6.35
7	128	1154.14	100 Year	4.08	131.11	131.77	131.78	131.94	0.073279	1.83	2.22	6.68
8	84	83.73	5 year	2.15	111.79	112.26	112.26	112.39	0.165237	1.55	1.39	5.84
8	84	83.73	20 Year	3.03	111.79	112.33	112.33	112.47	0.158522	1.66	1.82	6.64
8	84	83.73	50 Year	3.49	111.79	112.36	112.36	112.51	0.155657	1.71	2.04	7.01
8	84	83.73	100 Year	4.01	111.79	112.4	112.4	112.56	0.152821	1.76	2.28	7.42
8	84	220.37	5 year	2.15	111.81	113.03	112.31	113.04	0.001386	0.27	8.1	13.35
8	84	220.37	20 Year	3.03	111.81	113.17	112.38	113.17	0.00149	0.31	9.97	14.68
8	84	220.37	50 Year	3.49	111.81	113.22	112.42	113.23	0.001542	0.33	10.79	15.23
8	84	220.37	100 Year	4.01	111.81	113.28	112.45	113.29	0.001586	0.35	11.7	15.82
8	84	333.35	5 year	2.15	115.13	115.26	115.26	115.33	0.196652	1.12	1.91	14.95
8	84	333.35	20 Year	3.03	115.13	115.3	115.3	115.38	0.181269	1.25	2.43	15.22
8	84	333.35	50 Year	3.49	115.13	115.31	115.31	115.4	0.175666	1.31	2.67	15.34
8	84	333.35	100 Year	4.01	115.13	115.33	115.33	115.42	0.171458	1.36	2.94	15.47
8	84	452.28	5 year	2.15	115.54	116.48	116	116.49	0.003093	0.37	5.85	11.68
8	84	452.28	20 Year	3.03	115.54	116.59	116.06	116.6	0.003309	0.43	7.19	12.71
8	84	452.28	50 Year	3.49	115.54	116.64	116.09	116.65	0.003417	0.46	7.83	13.2
8	84	452.28	100 Year	4.01	115.54	116.69	116.12	116.71	0.003525	0.49	8.53	13.71
8	84	603.85	5 year	2.15	118.54	118.65	118.65	118.71	0.254988	1.07	2.01	20.58
8	84	603.85	20 Year	3.03	118.54	118.68	118.68	118.74	0.195673	1.12	2.7	21.04
8	84	603.85	50 Year	3.49	118.54	118.69	118.69	118.76	0.194258	1.18	2.95	21.21
8	84	603.85	100 Year	4.01	118.54	118.71	118.71	118.78	0.183019	1.22	3.28	21.42
8	84	711.85	5 year	2.15	118.32	119	118.55	119.01	0.000743	0.19	13.5	29.35
8	84	711.85	20 Year	3.03	118.32	119.08	118.58	119.09	0.000903	0.22	15.87	29.98
8	84	711.85	50 Year	3.49	118.32	119.13	118.59	119.13	0.000949	0.24	17.13	30.3
8	84	711.85	100 Year	4.01	118.32	119.17	118.61	119.17	0.001004	0.26	18.41	30.64
9	130	130.42	5 year	3	83.12	83.62		83.67	0.014221	1.03	2.93	10.31
9	130	130.42	20 Year	4.17	83.12	83.94	83.58	83.95	0.002449	0.61	6.79	13.79
9	130	130.42	50 Year	4.86	83.12	84.07	83.61	84.09	0.001852	0.55	8.83	17.14
9	130	130.42	100 Year	5.49	83.12	84.18	83.64	84.2	0.001362	0.5	11	20.71
9	130	241.16	5 year	3	85.18	85.46	85.42	85.51	0.019664	1.02	3.24	23.23
9	130	241.16	20 Year	4.17	85.18	85.47	85.47	85.55	0.028939	1.29	3.62	24.72
9	130	241.16	50 Year	4.86	85.18	85.49	85.49	85.58	0.028351	1.35	4.12	26.42
9	130	241.16	100 Year	5.49	85.18	85.51	85.51	85.6	0.026901	1.38	4.64	28.21

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
0	20	19.82	PMF	211.9	79.89	81.4	81.19	81.69	0.01924	2.5	93.04	107.85
0	20	186.91	PMF	211.9	81.89	83.66	83.19	83.83	0.009008	1.92	121.27	110.49
0	20	327.95	PMF	211.9	83.47	85	84.73	85.16	0.010137	1.66	133.01	224.53
0	20	424.95	PMF	211.9	84.88	85.97	85.9	86.15	0.009755	1.45	118.23	144.21
0	20	512.91	PMF	211.9	84.88	86.65		86.72	0.00459	1.4	171.96	185.54
0	20	625.85	PMF	211.9	86.55	87.54	87.48	87.74	0.024123	2.09	107.98	191.64
0	20	762.98	PMF	211.9	86.86	88.82	88.47	88.89	0.004138	1.42	192.33	236.81
0	20	908.05	PMF	211.9	89.06	90.23	90.23	90.49	0.030387	2.69	95.77	184.51
0	20	1100.46	PMF	211.9	92.12	93.52	93.29	93.64	0.010078	1.73	144.1	219.65
0	20	1410.1	PMF	211.9	97.71	98.88	98.88	99.14	0.030808	2.67	96.28	184.74
1	0	0	PMF	1119.7	70.64	80.95	76.75	80.97	0.000049	1.11	2242.33	423.84
1	0	92.61	PMF	1119.7	70.94	80.95	75.03	80.97	0.000044	1.25	2235.95	392.77
1	0	210.03	PMF	1119.7	71.39	80.96	77.26	80.98	0.000056	1.3	2141.23	406.22
1	0	346.15	PMF	1119.7	72	80.95		81.01	0.000134	1.75	1407.61	295.17
1	0	359.39	PMF	1119.7	72.1	80.97	77.84	81.01	0.000118	1.58	1529.21	342.1
1	0	427.63	PMF	1119.7	72.35	80.97	78.07	81.02	0.000148	1.65	1414.64	335.5
1	0	500.53	PMF	1119.7	72.65	80.83	79.02	81.11	0.000585	2.87	612.88	160.9
1	0	566.93	PMF	1119.7	72.9	80.87		81.17	0.001009	3.1	582.26	178.2
1	0	729.84	PMF	1119.7	73.52	81.25	79.22	81.32	0.000404	1.53	1018.47	314.02
1	0	1122.99	PMF	1119.7	74.49	81.37		81.44	0.000737	1.65	1040.32	490.38
1	0	1273.6	PMF	1119.7	76.42	81.47	81.05	81.69	0.003789	2.92	591.25	463.79
1	0	1602	PMF	1119.7	79.23	83.11	82.98	83.39	0.008944	1.87	481.47	421.04
1	0	1819	PMF	1119.7	79.93	84.01	82.92	84.11	0.00227	1.23	824.92	461.35
1	0	2000	PMF	1119.7	80.4	84.37	83.54	84.48	0.003245	1.11	769.45	506.26
1	0	2142	PMF	1119.7	81.09	84.84	84.73	84.96	0.004189	1.21	746.37	566.58
1	0	2275	PMF	1119.7	81.56	85.73	85.73	85.85	0.002889	1.18	750.59	497.68
1	0	2415	PMF	1119.7	82.31	86.22	86	86.4	0.006042	1.32	607.35	445.07
1	0	2552	PMF	1119.7	82.81	86.94	86.57	87.08	0.00418	1.46	678.91	481.85
1	0	2718	PMF	1119.7	83.52	87.6	87.4	87.78	0.004962	1.44	630.59	480.67
1	3035	3035	PMF	407.2	83.86	88.42		88.44	0.000519	0.61	649.78	373.26
1	3035	3169	PMF	407.2	84.28	88.51		88.54	0.001243	0.84	500.49	375.55
1	3412	3412	PMF	488	85.34	88.96		89.38	0.012918	2.9	169.47	117.18
1	3412	3532	PMF	488	85.94	89.91		90.07	0.003169	1.64	281.91	177.32
1	3412	3613	PMF	488	86.48	90.17	89.46	90.26	0.002011	1.24	361.56	250.27
1	3412	3691	PMF	488	86.53	90.32	89.26	90.4	0.001601	1.33	401.52	291.2
1	3412	3836	PMF	488	86.92	90.93	90.93	91.85	0.017905	4.02	115.09	125.57
1	3412	4010	PMF	488	87.76	92.02	91.5	92.04	0.00021	0.41	728.94	401.25
1	3412	4135	PMF	488	88.36	93	93	93.11	0.00155	1.67	337.05	178.73
1	3412	4136		Bridge								
1	3412	4141	PMF	488	88.36	93.46	93	93.53	0.000754	1.25	419.76	178.73
1	3412	4220	PMF	488	88.77	93.54	92	93.56	0.000121	0.31	918.26	339.39
1	3412	4266	PMF	488	89.34	93.55	92.77	93.58	0.00045	0.67	628.22	325.2
1	3412	4535	PMF	488	90.13	94	94	94.08	0.001716	1.17	401.86	369.25
1	3412	4540		Bridge								
1	3412	4545	PMF	488	90.13	94.02	94	94.1	0.001605	1.14	410.09	369.25
1	3412	4780	PMF	488	91.5	94.56	94.4	94.87	0.008618	2.19	204.37	189.44
1	3412	4785		Culvert								
1	3412	4790	PMF	488	91.5	94.78	94.5	94.99	0.004738	1.76	246.42	189.44
1	3412	5058	PMF	488	92.71	96.08	95.62	96.21	0.004063	1.78	302.07	278.36
1	3412	5519	PMF	488	94.81	98	98	98.05	0.001034	0.75	506.7	405.86
1	3412	5524		Culvert								
1	3412	5529	PMF	488	94.81	98.02	98	98.07	0.000994	0.74	513.83	407.92
1	3412	5836	PMF	488	96.67	100.56	100.56	101.05	0.013563	3.89	163.54	158.7
1	3412	5840		Culvert								
1	3412	5846	PMF	488	96.67	99.86	100.56	102.61	0.120316	9.32	70.87	103.45
1	3412	5904	PMF	488	97	99.26	99.26	124.75	0.897027	24.03	24.43	182.92
1	3412	6338	PMF	488	98.71	102.95	102.95	103.48	0.012927	5.23	180.06	153.12
2	157	156.55	PMF	175.2	86.97	88.76		88.82	0.00477	1.19	155.92	153.07
2	157	260.99	PMF	175.2	87.78	89.16		89.2	0.002875	0.83	193.64	176.8
2	537	537.21	PMF	102.5	89.39	90.09	89.85	90.12	0.004413	0.71	128.15	290.89
2	537	721.8	PMF	102.5	91.65	92	92	92.09	0.015383	0.84	80.89	226.28
2	537	925.54	PMF	102.5	94.24	94.86		94.93	0.012603	1.13	84.9	199.45
2	537	1115.38	PMF	102.5	96.66	97.43		97.55	0.014978	1.43	66.53	128.99
2	537	1335.64	PMF	102.5	98.54	99.62		99.7	0.006735	1.23	83.24	119.2
2	537	1538.74	PMF	102.5	100.68	101.7		101.9	0.019412	1.98	51.77	77.5
2	537	1755.04	PMF	102.5	103.6	105.13	104.95	105.3	0.012907	2.12	58.33	83.16
2	537	1940.92	PMF	102.5	107.47	108.58	108.58	108.86	0.031024	2.7	43.78	77.33
2	537	2128.69	PMF	102.5	111.8	112.96		113.15	0.017476	2.07	53.66	83.58
2	537	2284.88	PMF	102.5	115.11	116.21	116.16	116.47	0.025978	2.39	45.56	73.72
2	537	2443.45	PMF	102.5	119.98	120.78	120.78	121.04	0.032015	2.19	46.42	93.48

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)
3	126	125.72	PMF	107.8	88.72	89.61		89.67	0.006353	0.98	98.83	161.76
3	126	289.48	PMF	107.8	89.32	90.78	90.58	90.87	0.008207	1.49	85.46	153.17
3	126	505.92	PMF	107.8	91.65	92.8	92.77	93.3	0.030165	2.72	34.66	32
3	126	515		Bridge								
3	126	524.98	PMF	107.8	91.71	93.48	92.82	93.5	0.001711	0.86	182.62	303.69
3	126	606.02	PMF	107.8	92.58	93.65	93.15	93.7	0.003256	0.81	108.01	115
3	126	770.49	PMF	107.8	94.28	95.06	95.14	95.38	0.03195	1.91	47.83	109.42
3	126	935.46	PMF	107.8	96.78	98	98	98.14	0.010222	1.63	65.9	84.32
3	126	1082.88	PMF	107.8	98.15	100.13	100.13	100.83	0.032395	3.86	29.58	75.08
3	126	1235.08	PMF	107.8	100.88	102.37	101.94	102.45	0.004953	1.29	87.28	108.73
4	365	365.4	PMF	636	85.65	89.63		89.78	0.006583	1.56	381.6	345.01
4	365	519.85	PMF	636	86.61	91.04	91.04	91.35	0.018009	3.08	280.18	370.07
4	365	814.66	PMF	636	88.17	93.36		93.55	0.004284	2.12	383.02	318.11
4	365	1023.34	PMF	636	88.69	94.48		94.71	0.007864	2.35	321.14	254.69
4	365	1279.22	PMF	636	89.92	95.93		96.08	0.004493	1.98	390.38	279.54
4	365	1486.1	PMF	636	91.48	96.84		97.11	0.005519	2.39	306.84	236.18
4	365	1954.29	PMF	636	93.91	99.72	98.37	100.07	0.007428	2.79	276.16	227.35
4	365	1955		Lat Struct								
4	365	2157.14	PMF	636	95.37	101.45	101.36	101.78	0.009669	2.82	292.95	297.6
4	365	2320.86	PMF	636	96.57	102.59		102.79	0.004475	2.27	363.84	272.78
4	2554	2554.03	PMF	192.4	98.54	103.67		103.9	0.005611	2.22	94.18	42.55
4	2554	2771.86	PMF	192.4	102.34	105.59	105.34	106.19	0.025598	3.56	56.55	32.12
4	2554	2911.18	PMF	192.4	104.46	108.44	107.82	108.89	0.015038	3.09	67	35.83
4	2554	3134.45	PMF	192.4	105.69	110.64	109	110.88	0.006002	2.2	90.68	32.17
4	3327	3327.25	PMF	141.9	107.82	112.06		112.29	0.009895	2.14	66.96	31.62
4	3327	3480.2	PMF	141.9	109.47	114.01		114.43	0.019911	2.88	49.28	21.81
4	3327	3612.52	PMF	141.9	112.73	116.73		117.28	0.022692	3.35	43.65	21.79
4	3327	3743.03	PMF	141.9	116.63	119.88		120.41	0.025473	3.31	44.75	27.5
4	3327	3856.87	PMF	141.9	116.67	121.41		121.57	0.005248	1.86	86.47	64.26
4	3327	3989.54	PMF	141.9	118.32	122.39		123.07	0.027311	3.71	39.64	19.73
4	3327	4105.66	PMF	141.9	119.31	124.45	123.07	124.74	0.008582	2.42	60.49	23.3
4	3327	4224.73	PMF	141.9	122.76	126	126	126.8	0.039269	4.09	36.39	22.67
4	3327	4317.29	PMF	141.9	123.37	128.03		128.36	0.008967	2.67	56.46	24.47
4	3327	4415.58	PMF	141.9	125.97	128.89	127.94	129.04	0.006026	1.74	81.11	45.08
5	35	34.83	PMF	413.9	97.54	103.1		103.13	0.000489	0.84	563.85	246.22
5	35	139.68	PMF	413.9	98.15	103.12	100.82	103.16	0.000697	0.94	497.79	222.05
5	287	287.07	PMF	393.3	99.34	103.18	103.55	104.14	0.031147	4.48	101.33	127.08
5	287	300		Bridge								
5	287	314.64	PMF	393.3	99.34	104.35	103.55	104.45	0.002437	1.63	298.95	183.4
5	287	584	PMF	393.3	101.6	105.58	105.18	105.93	0.007693	2.72	162.19	129.27
5	883	883.08	PMF	380.7	103.62	107.64		107.9	0.005641	2.34	171.9	85.87
5	883	1137.7	PMF	380.7	105.43	108.81	108.23	109.15	0.007255	2.69	147.46	72.18
5	883	1287.21	PMF	380.7	106.56	110.24	110.23	111	0.022598	4.27	99.52	62.79
5	883	1457.84	PMF	380.7	108.4	112.97	112.71	113.45	0.010966	3.7	128.1	73.2
5	883	1561.13	PMF	380.7	111.57	114.85	114.85	115.62	0.019362	4.27	100.26	60.72
5	883	1665.27	PMF	380.7	114.05	116.92		117.56	0.017663	3.82	109.47	62.19
5	883	1769.01	PMF	380.7	115.52	118.76	118.68	119.76	0.023291	4.73	87.41	43.36
5	883	1859.76	PMF	380.7	116.76	120.73	120.51	121.67	0.018955	4.67	90.8	41.49
5	883	1964.51	PMF	380.7	118.44	122.63	122.23	123.29	0.012579	3.98	111.11	59.11
5	883	2046.72	PMF	380.7	120.51	124.19	124.18	125.34	0.024016	5.11	81.66	35.4
6	136	135.86	PMF	19.7	105.26	106.82	105.84	106.84	0.000913	0.57	42.68	61.34
6	136	221.44	PMF	19.7	107.34	108.1	108.1	108.28	0.032596	1.97	11.47	38.94
6	136	325.77	PMF	19.7	110.77	111.35		111.48	0.028726	1.63	12.38	32.06
6	136	435.55	PMF	19.7	111.67	113.19	112.95	113.33	0.01098	1.9	12.94	19.93
6	136	508.23	PMF	19.7	114.69	115.52	115.72	116.14	0.121525	3.8	5.79	14.21
6	136	620.35	PMF	19.7	122.62	123.29	123.29	123.47	0.040268	2.05	10.92	32.69
7	128	127.73	PMF	34	103.08	103.87	103.87	104.22	0.054699	2.63	12.95	18.71
7	128	266.37	PMF	34	104.55	106.28	105.74	106.4	0.007275	1.64	22.27	20.43
7	128	433.14	PMF	34	107.42	108.79	108.79	109.17	0.036797	2.87	12.84	17.44
7	128	612.82	PMF	34	110.78	111.47	111.84	113.07	0.589525	5.64	6.18	19.61
7	128	680.22	PMF	34	115.94	117.02	117.02	117.14	0.020759	1.99	27.74	136.06
7	128	763.09	PMF	34	115.84	117.25	116.52	117.26	0.000396	0.34	113.1	134.77
7	128	946.58	PMF	34	121.41	122.23	122.23	122.46	0.046435	2.46	16.4	36.6
7	128	1041.45	PMF	34	125.31	126.07	126.24	126.63	0.097146	3.48	10.45	21.27
7	128	1154.14	PMF	34	131.11	132.68	132.68	133.09	0.037722	2.92	12.42	15.81
8	84	83.73	PMF	40.9	111.79	113.35	113.35	113.83	0.089354	3.12	14.8	18.75
8	84	220.37	PMF	40.9	111.81	114.98	113.42	115.02	0.002915	0.99	56.6	50.15
8	84	333.35	PMF	40.9	115.13	116.07	116.07	116.33	0.072261	2.34	19.45	43.27
8	84	452.28	PMF	40.9	115.54	118.1	117.09	118.18	0.006477	1.34	56.81	62.9
8	84	603.85	PMF	40.9	118.54	119.65		119.76	0.019805	1.48	33.25	51.38
8	84	711.85	PMF	40.9	118.32	120.37	119.18	120.4	0.002837	0.82	61.67	41.66

APPENDIX G- MUSIC PARAMETERS & RESULTS

Source nodes	Type 1- End of Pipe wetland			Type 2 - WSUD			Type 3 - Rural residential		
Subcatchment	Roof(imp)	Garden (perv)	Road (imp)	Road (imp)	Roof(imp)	garden (perv)	Road (imp)	Roof(imp)	rural garden (perv)
Total Area (ha)	0.45	0.35	0.2	0.2	0.45	0.35	0.1	0.3	0.6
Area Impervious (ha)	0.45	0	0.2	0.2	0.45	0	0.1	0.3	0
Area Pervious (ha)	0	0.35	0	0	0	0.35	0	0	0.6
Field Capacity (mm)	100	55	100	100	100	55	100	100	55
Pervious Area Infiltration Capacity coefficient - a	300	102	300	300	300	102	300	300	102
Pervious Area Infiltration Capacity exponent - b	2	1	2	2	2	1	2	2	1
Impervious Area Rainfall Threshold (mm/day)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Pervious Area Soil Storage Capacity (mm)	239	72	239	239	239	72	239	239	72
Pervious Area Soil Initial Storage (% of Capacity)	30	30	30	30	30	30	30	30	30
Groundwater Initial Depth (mm)	10	10	10	10	10	10	10	10	10
Groundwater Daily Recharge Rate (%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Groundwater Daily Baseflow Rate (%)	5	5	5	5	5	5	5	5	5
Groundwater Daily Deep Seepage Rate (%)	0	0	0	0	0	0	0	0	0
Stormflow Total Suspended Solids Mean (log mg/L)	1.54	2.2	2.4	2.4	1.54	2.2	2.4	1.54	2.2
Stormflow Total Phosphorus Mean (log mg/L)	-0.85	-0.39	-0.56	-0.56	-0.85	-0.39	-0.56	-0.85	-0.6
Stormflow Total Nitrogen Mean (log mg/L)	0.3	0.46	0.32	0.32	0.3	0.46	0.32	0.3	0.3
Baseflow Total Suspended Solids Mean (log mg/L)	1.54	1.17	2.4	2.4	1.54	1.17	2.4	1.54	1.17
Baseflow Total Phosphorus Mean (log mg/L)	-0.85	-0.82	-0.56	-0.56	-0.85	-0.82	-0.56	-0.85	-0.6
Baseflow Total Nitrogen Mean (log mg/L)	0.3	0.3	0.32	0.32	0.3	0.3	0.32	0.3	0.3
OUT - Mean Annual Flow (ML/yr)	3	0.276	1.33	1.33	3	0.276	0.667	2	0.473
OUT - TSS Mean Annual Load (kg/yr)	104	43.3	335	335	104	43.3	167	69.3	74.3
OUT - TP Mean Annual Load (kg/yr)	0.424	0.112	0.367	0.367	0.424	0.112	0.184	0.282	0.119
OUT - TN Mean Annual Load (kg/yr)	5.99	0.793	2.79	2.79	5.99	0.793	1.39	3.99	0.944
OUT - Gross Pollutant Mean Annual Load (kg/yr)	86.3	0	38.4	38.4	86.3	0	19.2	57.5	0

Treatment Nodes	Type 1 - Constructed Wetland	Type 2 - Bio-Retention Area		Type 3 - rural Residential
Water quality Control	**Constructed wetland**	**Bio-Retention Area**	**Permeable pavers**	**Bio-Retention Area**
Node Type	WetlandNode	BioRetentionNode	SedimentationBasinNode	BioRetentionNode
Lo-flow bypass rate (cum/sec)	0	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100	100
Inlet pond volume	0		0	
Area (sqm)	200	140	300	50
Extended detention depth (m)	0.6	0.35	0.3	0.35
Permanent pool volume (cum)	165		10	
Proportion vegetated	0.5		0	
Equivalent pipe diameter (mm)	19		21	
Overflow weir width (m)	3	5	2	5
Notional Detention Time (hrs)	51.2		44.4	
Orifice discharge coefficient	0.6		0.6	
Weir coefficient	1.7	1.7	1.7	1.7
Number of CSTR cells	5	3	1	3
Total Suspended Solids k (m/yr)	1500	8000	8000	8000
Total Suspended Solids C* (mg/L)	6	20	20	20
Total Suspended Solids C** (mg/L)	6		20	
Total Phosphorus k (m/yr)	1000	6000	6000	6000
Total Phosphorus C* (mg/L)	0.06	0.13	0.13	0.13
Total Phosphorus C** (mg/L)	0.06		0.13	
Total Nitrogen k (m/yr)	150	500	500	500
Total Nitrogen C* (mg/L)	1	1.4	1.8	1.4
Total Nitrogen C** (mg/L)	1		1.4	
Threshold hydraulic loading for C** (m/yr)	3500		3500	
Extraction for Re-use	Off	Off	Off	Off
Filter area (sqm)		80		25
Filter depth (m)		0.6		0.6
Filter median particle diameter (mm)		4		4
Saturated hydraulic conductivity (mm/hr)		100		100
Voids ratio		0.3		0.3
Seepage Rate (mm/hr)	0.5	0.5	0	0.5
Evap Loss as proportion of PET	1.25		0.5	
Depth in metres below the drain pipe		0		0
IN - Mean Annual Flow (ML/yr)	4.41	4.36	3	2.79
IN - TSS Mean Annual Load (kg/yr)	176	396	104	194
IN - TP Mean Annual Load (kg/yr)	0.693	0.811	0.424	0.491
IN - TN Mean Annual Load (kg/yr)	8.8	8.53	5.99	4.32
IN - Gross Pollutant Mean Annual Load (kg/	118	36.5	86.3	65
OUT - Mean Annual Flow (ML/yr)	3.23	4.25	2.8	2.77
OUT - TSS Mean Annual Load (kg/yr)	69.3	45.3	57.6	59.9
OUT - TP Mean Annual Load (kg/yr)	0.356	0.303	0.366	0.285
OUT - TN Mean Annual Load (kg/yr)	5.2	5.31	5.17	3.36
OUT - Gross Pollutant Mean Annual Load (k	0	0	0	0

Note: buffer strips applied to impervious surfaces idenified as not being directly connected to drainage ie. Footpath or house in rural residential lots

APPENDIX H – STREAM ORDER DETERMINATION

3.2 Consent from Cessnock City Council

<u>Dimensions of example 0.5 megalitre dams</u>

A **roughly circular** dam approximately 2 metres deep, 25 metres wide and 30 metres long is just below 0.5 megalitres in size.

A **square** dam approximately 2 metres deep, 25 metres wide and long is 0.5 megalitres in size.

2. You will need to apply to Council for consent for a dam (under the Environmental Planning and Assessment Act) where the dam (or an extension to an existing dam) is:

1. one of the types of dams listed above that require a DLWC approval; or
2. to be located on a 1st or 2nd order watercourse (this includes off stream structures within the catchment of 1st or 2nd order watercourses) over 0.5 megalitres (500 cubic metres); or
3. an off-stream structure licenced under the Water Management Act to hold water extracted from a river or groundwater; or
4. an off-stream structure in the Pokolbin Private Irrigation District; or
5. any structure licensed under the Protection of the Environment Operations Act

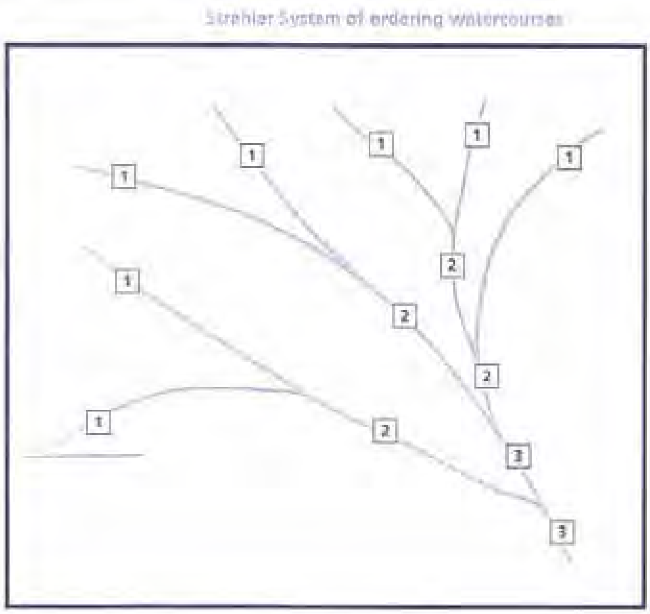
If your dam falls into one of these categories, you should use this Plan to prepare your development application to submit to Council.

You may also apply to Council for a Construction Certificate for the dam at the same time as making the development application.

See page 7 for other legislation that may also affect your application.

Stream order

The following diagram and text describes the definitions of 'stream orders'. Note that the stream orders in the Cessnock City Council area can be viewed at Council.



The Strahler system explained

- Starting at the top of a catchment, any watercourse which has no other watercourses flowing into it is classed as a 1st order watercourse (1).
- Where two 1st order watercourses join, the watercourse becomes a 2nd order watercourse (2).
- If a 2nd order watercourse is joined by a 1st order watercourse - it remains a 2nd order watercourse.
- When two or more 2nd order watercourses join they form a 3rd order watercourse (3).
- A 3rd order watercourse does not become a 4th order watercourse until it is joined by another 3rd order watercourse.
- and so on.

(Source: Department of Land and Water Conservation 'Farm Dams Assessment Guide')

APPENDIX I – HARVESTABLE RIGHTS CALCULATIONS

6873 - North Bellbird
Harvestable Rights Estimation

Site Area (km²)	**4.97**
Site Area (ha)	**497**
Harvestable Rights Multiplier (ML/ha)	**0.82**
Harvestable Rights (ML)	**408**

Total Farm Dams on Rezoning Land (ML) **41**
Estimated Maximum Wetland Volume (ML) ***65***
Proposed Wetland Volume (ML) ***37*** *refer to Appendix J*

	Surface Area (m²)	Estimated Average Depth (m)	Volume (m³)	Volume (ML)
Existing Farm Dams				
1	761	1	761	0.761
2	290	1	290	0.29
3	834	1	834	0.834
4	145	1	145	0.145
5	2216	1	2216	2.216
6	694	1	694	0.694
7	465	1	465	0.465
8	1329	1	1329	1.329
9	1300	1	1300	1.3
10	968	1	968	0.968
11	406	1	406	0.406
12	966	1	966	0.966
13	2566	1	2566	2.566
14	3817	1	3817	3.817
15	2687	1	2687	2.687
16	884	1	884	0.884
17	1642	1	1642	1.642
18	1760	1	1760	1.76
19	837	1	837	0.837
20	584	1	584	0.584
21	727	1	727	0.727
22	612	1	612	0.612
23	838	1	838	0.838
24	1330	1	1330	1.33
25	349	1	349	0.349
26	151	1	151	0.151
27	584	1	584	0.584
28	247	1	247	0.247
30	1545	1	1545	1.545
31	1819	1	1819	1.819
32	7392	1	7392	7.392

APPENDIX J – PRELIMINARY STORMWATER CONTROL REQUIREMENTS

Estimated Stormwater Control Requirments

Subcatchment ID	Subcatchment Area (ha)	Subcatchment Impervious Area (ha)	Percentage Impervious (%)	Treatment Type	Type - 1				Type - 2			Type - 3	
					Wetland Area (m2)	Extended Detention (m3)	Active Detention Storage (m3)	Estimated Basin Area (m2)	Bio-Retention Filter Surface Area (m2)	Extended Detention (m3)	Active Detention Storage (m3)	Bio-Retention Filter Surface Area (m2)	Extended Detention (m3)
14.01A	7.6	4.9	65	2	-	-	-	-	608	912	494	-	-
14.02A	25.2	16.4	65	1	5040	3276	921	7289	-	-	-	-	-
14.02B	5.7	3.7	65	1	1142	742	304	1925	-	-	-	-	-
10.04A	11.1	7.2	65	1	2222	1444	703	3770	-	-	-	-	-
10.03A	6.6	4.3	65	1	1320	858	438	2550	-	-	-	-	-
15	19.1	12.4	65	1	3820	2483	1242	6200	-	-	-	-	-
15.01	26.8	17.4	65	2	-	-	-	-	2144	3216	1742	-	-
15.02	23.9	15.5	65	1	4780	3107	1554	7000	-	-	-	-	-
10.06B	7.2	4.7	65	2	-	-	-	-	576	864	468	-	-
10.06A	12.8	8.3	65	1	2560	1664	1144	4528	-	-	832	-	-
10.06C	4.2	2.7	65	2	-	-	-	-	336	504	273	-	-
20.03A	5.7	3.7	65	2	-	-	-	-	457	685	371	-	-
24.01 A	18.8	12.2	65	2	-	-	-	-	1504	2256	1222	-	-
20.04A	5.8	3.5	60	2	-	-	-	-	465	697	378	-	-
25.00A	8.6	3.4	40	3	-	-	-	-	-	-	-	215	258
27.00A	6.2	2.5	40	3	-	-	-	-	-	-	-	155	186
20.06A	10.6	6.9	65	1	2120	1378	809	3240	-	-	-	-	-
20.07A	20.5	13.3	65	2	-	-	-	-	1641	2461	1333	-	-
28.00 / 28.01A	67.3	34.5	51	1	13454	6904	6209	17025	-	-	-	-	-
20.09A	14.4	9.4	65	2	-	-	-	-	1152	1728	936	-	-
1.04A	13.4	8.7	65	2	-	-	-	-	1072	1608	871	-	-
1.05A	2.4	1.6	65	2	-	-	-	-	192	288	156	-	-
Total	**324**	**197**			**36458**	**21856**	**13324**	**53527**	**10146**	**15220**	**9076**	**370**	**444**

NOTE: Estimated stormwater control requirements area based on the provided development master plan and are indicative only. A more detailed investigation of stormwater controls will be required at the Development Application stage.

APPENDIX K – CORRESPONDENCE

NSW Government

DEPARTMENT OF NATURAL RESOURCES

Your Ref: DA18/2006/6/1
Our Ref: ER7111

10 November 2006

Neil Selmon
Cessnock City Council
PO Box 152
CESSNOCK NSW 2325

Attention: Neil Selmon

Dear Sir

PROPOSED AMENDMENT TO CESSNOCK LEP 1989 NO.121
BELLBIRD NORTH PRECINCT

I refer to Council's letters dated 19 September 2006 and 25 October 2006 concerning the above proposal. The additional information requested by the Department has been received and reviewed. This information largely related to issues associated with flooding and zoning clarification. It is of concern to the Department the lack of review and assessment by Council of these issues prior to the s62 consultation.

The considerable information provided has now been reviewed by the Department of Natural Resources (DNR). DNR has no objections to the proposed amendment provided the following comments are addressed.

Riparian Corridors
DNR is responsible for the administration of the *Rivers and Foreshores Improvement Act 1948* (RFIA). The intent of the RFIA is to prevent erosion or degradation of *'protected lands'* as defined in section 22A of the *Act*. A permit under Part 3A of the RFIA is necessary to approve works that have the potential to cause adverse impacts on *'protected waters'*, such as increased erosion or sedimentation, bed lowering and bank collapse and obstructing or detrimentally affecting stream flow, leading to long term stability problems.

Any works which involve excavation on *'protected land'* will require a permit under the RFIA. In order to avoid the need for referral of future development applications to DNR, Council is encouraged to ensure that development is excluded from these areas via appropriate zoning. A copy of key definition under the RFIA is attached as an Annexure.

There are a number of on site minor streams, creeks and rivers. The following standard riparian buffer widths are required to ensure that the intent of the RFIA is achieved:

- 10m – minor streams
- 20m – minor creeks
- 30m - minor rivers and minor wetlands

In addition, Land and Water Australia have defined buffer widths in terms of specific management objectives that relate to different aspects of river health. These are listed in Fact Sheet 13 "Managing riparian widths" (available from www.rivers.gov.au). Those that relate to the site are listed below.

To improve water quality
Wherever possible, preserve and improve existing native riparian vegetation to provide a minimum 10 metre (m) width upslope (away from) the top of the banks. Where no riparian vegetation is present, native species should be replanted, so that this vegetation forms a 10m riparian buffer.

To reduce erosion of stream banks
Wherever possible, preserve and enhance existing native riparian vegetation to provide a minimum width upslope (away from) from the top of the bank of 5m, plus the height of the bank, plus an additional width if the bank is actively eroding. The erosion allowance is calculated as the rate of bank erosion in metres per year, multiplied by the number of years it will take for replanted vegetation to reach maturity or a height of 10m (use the lesser period).

To maintain natural light and temperature levels within streams
Two to three tree or tall shrub widths (10-20m) need to be maintained, though a minimum of one tree or tall shrub width (5-10m) will provide shade and reduce temperature levels. Widths may therefore vary from between 5-20m, depending on the species used and the site. Higher rainfall areas will need a continuous strip of native riparian species to mimic natural conditions, whilst in drier inland areas riparian cover may be discontinuous.

To provide food inputs and habitat for aquatic ecosystems
Ideally, two to three tree or tall shrub widths (10-20m) need to be maintained, though a minimum of one tree or tall shrub width (5-10m) will still provide inputs if it has a healthy crown overhanging the stream.

The Department supports the development of a seamless riparian corridor. Local native plant species should be used in rehabilitation and a buffer provided along the length of watercourses. The vegetation should extend down the bank to at least the average low water level.

All structural works, including works for stormwater capture and treatment should be located outside the riparian buffer.

Asset Protection Zones (APZ) required for bushfire protection under the Rural Fires Act 1997 should be contained within the development envelope and not impinge upon riparian or remnant vegetation. Figure 3 (Bushfire Planning Assessment Report) indicates however that the APZs are proposed to occur within remnant vegetation.

Riparian and remnant vegetation management
DNR is the governing agency charged with ensuring that our native vegetation is protected. The proposed development will result in the direct loss of habitat for endangered ecological communities and further indirect losses of habit due to fragmentation and edge effects. The site covers about 496 ha, much of it already cleared. The remaining remnants, much of it confined to riparian corridors, are important to the site and local area in terms of providing habitat and limited connectivity. Although defined as ecologically constrained land, parts of these remnants have been earmarked for clearing (see Figure 11 in Anne Clements & Associates Report):

- 7.693 ha and 2.520 ha to the southwest,
- 1.030 and 3.063 ha to the south east corner,
- 0.329 ha to the north western corner.

Some of the above vegetation is in good condition with a high species diversity, particularly that vegetation to the south of the Site adjoining Limestone Creek. Ecologically endangered communities, the Lower Hunter Spotted Gum-Iron bark and the Hunter Lowland Redgum Forest will be cleared for development. Both these communities are located on land identified as ecologically constrained. The Hunter Lowland Redgum Forest, found in open depressions and drainage flats can be considered a potential groundwater dependent ecosystem. The impact to groundwater dependent ecosystems must be considered under the NSW State Groundwater Dependent Ecosystems Policy.

It has been recommended that vegetation with more than 30% canopy cover be retained. However, given the limited amount of remaining native vegetation and the large areas of available cleared land, the Department recommends that development be confined to cleared areas only. The re-establishment of vegetation to the southwest of the site, while admirable, does not replace the nearby functioning ecosystem earmarked for clearing (see Figure 11). It takes many years before a rehabilitated ecosystem performs to the same standard as the replaced system.

Wetlands

The low lying areas within the site contain a number of natural wetlands that lead into the creek systems. The wetlands to the east of the site contain both diverse and unique vegetation. In stream wetlands occur along the slow flowing sections of Bellbird and Limestone Creeks. NSW Wetlands are protected by a range of policies, legislation, planning instruments and international agreements. It is the policy of the NSW Government to promote the conservation, sustainable management and wise use of wetlands for the benefit of present and future generations. A buffer of 30m is required for wetlands within this site.

To minimise the impact of the proposed development on the wetlands, current hydrological regimes and pre-development flows should be maintained. Sediment and nutrient control devices should be installed as appropriate to protect instream and wetland water quality.

Farm dams

There are a number of farm dams within the proposed site. Prior to any rezoning, the current legal status and intended use of these farm dams needs to be determined, as the legal status of these structures will most likely be affected by any subsequent subdivision or development.

DNR administers approvals under *Water Act 1912 (WA)* and the *Water Management Act 2000 (WMA)*. To determine the necessary approvals in relation to the existing dams within the proposed site, the Department will therefore require the proponent to provide:

1. Clarification regarding the intended use of the existing dams;
2. Clarification if the dams comply with the State Farm Dams Policy in respect of the Maximum Harvestable Right Dam Capacity;
3. Advice if the dams are licensed under Part 2 of the *WA;*
4. The date of construction of the dams;
5. The size and storage capacity for each dam;
6. Construction details of the dams to include wall height, bywash dimensions, low flow pipes or other features/fixtures installed in the dams;
7. The current use/purpose of the dams (eg. stock and domestic);
8. Any proposal to change the purpose of the dams;
9. Clarification if the dams are on a creek line or otherwise;
10. Details if the dams are affected by flood flows;
11. Details of any proposal for shared use, rights and entitlement to the dams; and
12. Details of any other person/party to be supplied water from the dams (eg. volume, rate, and purpose).

For details about the Farm Dams Assessment Guide and information on Harvestable Rights, calculation of the MHRDC see http://www.naturalresources.nsw.gov.au/water/farm_dams/index.shtml

Groundwater
The site is located on the Hunter Valley floodplain. Bellbird and Limestone Creek have extended lengths of dry creek beds separated by a series of pools, suggesting that these creeks are groundwater fed (ie groundwater dependent ecosystems). The impact on groundwater was not however considered in the documentation provided. Details of groundwater depth were not provided and the potential to intercept groundwater not considered. Key groundwater issues should be identified, including any potential degradation issues.

Salinity
An assessment of the site, including the information provided by the proponent suggested the presence of saline soils, the disturbance of which could generate salts which could affect instream water quality. Further investigation is required to identify those areas with saline soils and appropriate mitigation measures developed to minimise the impact on stream water quality, foundation design and site stability.

Stormwater control and treatment
The Flooding and Stormwater Assessment (Appendix 13) recommends that detention storage and water control works are located offline from all existing major flow paths. The *Structure Plan* however indicates works for stormwater capture and treatment is located within the riparian buffer zone. In addition, the Plan shows some of these works to be online. The Department requires that all structural works, including works for stormwater capture and treatment, are located outside the riparian buffer. The Department will however consider the construction of online works on minor streams, with adequate justification.

Floodplain Management
Section 2.5 of the Rezoning Submission indicates that flooding is identified as a primary constraint to residential development. Areas which are flood liable are delineated in Figure 2.7 which shows the extent of flooding for various flood frequencies including the 1 in 100 year flood event and the PMF as determined in the Flood and Stormwater Assessment undertaken by Parsons Brinckerhoff. In terms of defining the constraint free land for the purposes of residential development, the Parsons Brickerhoff report recommends floor levels be a minimum of 500mm above the estimated 1 in 100 year flood level.

The Flood and Stormwater Assessment report shows the extent of flooding for various flood frequencies and has broadly assessed flood impacts of the proposed development. However, it should be noted that the report is limited in its scope and is not a floodplain management study or plan. It does not examine the array of floodplain management issues relating to this site that need to be identified and addressed.

The Rezoning Submission suggests that apart from additional hydraulic modelling that needs to be undertaken no further investigations are required. This is reinforced by the comments in the Table on page 76 concerning *Section 117 Directions* that suggests that *Direction 15 Flood Prone Land* has been complied with and that "Full consideration has been given to the level of flood affectation…" It is considered that the requirements of Direction No 15 have not been complied with and that further investigations are required to ensure that the rezoning proposal is in accordance with the NSW State Government's Flood Prone Lands Policy and Floodplain Development Manual, 2005.

Direction No 15 applies when a council prepares a draft LEP that creates, removes or alters a zone or a provision that affects flood prone land. The objective of this Direction is to ensure that development of flood prone land is consistent with the NSW State Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual. It is also to ensure that the provisions of an LEP on flood prone land are commensurate with the flood hazard and includes consideration of the potential impacts both on and off the subject land.

In effect, the Directive requires that rezoning of land is in accordance with a floodplain management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005. *Appendix I 6.3.7* of the Manual indicates that from a flood risk management perspective, rezoning applications need to be considered within a strategic framework of a floodplain management plan.

As there is no floodplain management plan for this area, a Plan will need to be prepared. The Manual outlines the process and requirements for the preparation of a Plan. This would include the following:

- *A comprehensive flood hazard assessment (in accordance with Appendix L of the Floodplain Development Manual):* It is advisable that development and particularly residential development be excluded from areas identified as high hazard;

- *Hydraulic categorisation including delineation of the floodway areas (in accordance with Appendix L of the Floodplain Development Manual):* It is noted that floodways are not delineated in the Flood and Stormwater Assessment. While the Table on page 76 of the Rezoning Submission indicates that development will not be undertaken in floodway areas page 19 of the Flood and Stormwater Assessment indicates that "filling of sections of Bellbird, Limestone and Lavender Creek defined channels and floodplain and adjacent tributaries" is an option for flood proofing those areas of the study area that are subject to inundation.

It is advisable that all development be excluded from floodway areas;

- *Impact of the development on local and downstream flooding:* While some broad brushed hydraulic modelling has been undertaken, further detailed modelling will be required to assess the potential flooding impacts of the development both locally and downstream (including various engineering works, roads, proposed detention basins and drainage works) once these details are known;

- *Impact of any proposed filling on local and downstream flooding*: As already noted, filling of land below the 1 in 100 year flood level is an option for consideration in the Flood and Stormwater Assessment. The potential flood impacts need to be assessed both locally and downstream;

- *A comprehensive assessment of flood warning, access, evacuation and emergency measures:* This should be undertaken in consultation with Council and the SES once the hazards and the nature of the flood risk has been identified.

It should be noted that the major creeks which traverse this area are subject to flash flooding. Flood waters can rise rapidly in a matter of hours with little warning time available. Under these circumstances, evacuation from low lying areas to higher ground (as suggested on page 20 of the Flood and Stormwater Assessment) may not be possible as access may be cut at relatively low flood levels isolating residents.

The implication of floods larger than the 1 in 100 year flood event with respect to evacuation and emergency response should also be considered. In this respect additional design floods may need to be modelled, for example the 1 in 200 year flood event. An area which needs to be examined carefully in terms of access and evacuation is the proposed residential development located between Limestone and Bellbird Creek where the creeks interact in floods larger than the 1 in 100 year flood as shown in Fig 2.7 of the Rezoning Submission. During a more extreme flood event there may not be sufficient warning time for evacuation and residents may be trapped by rising flood waters which could rise above the floor planning level.

- *Flood Development Control Plan: A* DCP should be prepared for this area which outlines development controls for all development (not just residential). It should be compatible with and in accordance with the Council's Flood Policy & planning instruments and the Floodplain Development Manual.

- *Black Creek Flood Study & Preparation of Cessnock Floodplain Management Plan.* You should be aware that Council has recently commissioned the Black Creek Flood Study. It will develop a two dimensional hydraulic model for Cessnock township and the North Bellbird Precinct Area. The model will integrate previous ad hoc flood studies undertaken of this area (including Lavender and Bellbird Creeks Flood Study January 2005 referenced in the Flood and Stormwater Assessment) and provide a better appreciation of the interaction of the major creeks including Black, Limestone, Bellbird and Lavender Creeks. This study will be followed by the preparation of a Floodplain Risk Management Study and Plan for the township.

It is suggested that the Rezoning Submission and Flood and Stormwater Assessment be submitted to Council's Floodplain Management Committee for review and comment.

Recommendations:
Should development of this site occur it is recommended that Council ensure that:

- All remaining riparian and remnant vegetation is protected.
- Degraded riparian vegetation is rehabilitated (as proposed).
- Degraded remnant vegetation is rehabilitated.
- Buffer zones implemented around wetland areas.
- The development footprint is confined to existing cleared areas only.
- An assessment of the impact of the proposed development on groundwater and groundwater dependent ecosystems, including wetlands is undertaken.
- Proposed APZs are confined to the development envelope.
- The use of Water Sensitive Urban Design principles are incorporated in the early stages of any development.
- Identification of saline areas and implementation of appropriate mitigation measures to protect site stability and instream water quality.
- The recommendations contained within the above floodplain management section are followed.

Should you wish to discuss matters relating to floodplain management, please contact Peter Medi, Senior Natural Officer, Coasts and Floodplain Management Unit. To discuss any of the other matters please contact me on (02) 4904 2540.

Yours sincerely

Laura Kuginis
Environmental Officer
Science and Information Division
Newcastle Office

Annexure

Definitions under Rivers and Foreshores Improvement Act 1948

The meanings under the RFIA for the following are:

1. *Protected* land means:
(a) Land that is the bank, shore or bed or *protected waters*, or
(b) Land that is not more than forty (40) metres from the top of the bank or shore of *protected waters* (measured horizontally from the top of the bank or shore), or
(c) Material at any time deposited naturally or otherwise and whether or not in layers, on or under land referred to in paragraph (a) or (b)

2. *Protected waters* means
"A *river*, lake into or from which a river flows, coastal lake or lagoon (including any permanent or temporary channel between a coastal lake or lagoon and the sea)".

3. *River* means
"Any stream of water, whether perennial or intermittent, flowing in a natural channel, or in a natural channel artificially improved, or in an artificial channel which has changed the course of the stream of water and any affluent, confluent, branch, or other stream into or from which the river flows and, in the case of a river running to the sea or into any coastal bay or inlet or into a coastal lake, includes the estuary of such river and any arm or branch of same and any part of the river influenced by tidal waters".

Any watercourse, whether perennial or ephemeral, is considered to be a 'river' as defined as in the Rivers and Foreshores Improvement Act, 1948. Under Part 3A of the Act any works within 40 metres of the top of both banks of a 'river' requires a permit. The department generally restricts any development within this 40 metres zone so as to ensure a riparian buffer for the 'river' is maintained and/or allowed to be rehabilitated.

[

APPENDIX 5

NORTH BELLBIRD PRECINCT

North Bellbird Rezoning – Stormwater and Floodplain Management Report - Worley Parsons, dated 29 October 2008.

WorleyParsons
resources & energy

Infrastructure
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Newcastle NSW 2300 Australia
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worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

29 October 2008

Ref: Lt_081029_bgp_6873 03_Response to Council Comments (revised final).doc

Johnson Property Group
PO Box A1308
South Sydney, NSW
1235

Attention Wade Morris

Dear Sir,

RE: North Bellbird Rezoning – Stormwater and Floodplain Management Report - Response to Council Comments

This letter provides our initial responses to comments received by Council in a letter dated the 30th September, 2008, and after clarification sought at our meeting dated 3 October 2008 at Cessnock City Council. The letter discusses Council's concerns with the flooding and stormwater aspects of the North Bellbird Residential Development rezoning application.

Existing Farm Dams

Johnson Property Group (*JPG*) proposed to decommission all farm dams within the proposed residential areas to improve the environmental functions of the on-site watercourses. This is consistent with DWE policy. In addition, the existing dams are too small to provide any measureable reduction in peak flows during a significant flood event. Accordingly, the removal of any dams would not increase the severity of downstream flooding.

Dams located outside of the proposed residential area, such as the large dam in Lot 1 DP 196460, could be maintained, provided the land-owner maintains licence arrangements with the Department of Water and Energy (DWE), as stipulated in a letter from the *Department of Natural Resources*, dated the 10th of November, 2006. (*this letter is attached in Appendix K of the flooding stormwater strategy*). It is noted that where farm dams are to be retained, it will be up to the owner/operator to ensure that the dam complies with relevant DWE and dam safety requirements.

Council has requested clarification as to whether the retention of the large farm dams in Lot 1 DP 196460 (*through the potential threat of future failure of these dams*) would warrant any adjustment to the rezoning boundaries proposed by JPG. An outline of our investigations to date is outlined below:

- Review of the available information from the Landholder Mr Robert Foggo indicates that the *Soil Conservation Service of the Department of Lands* constructed the two main dams on Mr Foggo's property. Records indicate that the original estimates called for the main dam having a volume of approximately 10-12 ML, (refer **Attachment A**). Recent estimates by the landholder (*pers. comm. Mr Robert Foggo*) indicate some 20ML of storage within this large dam and the second, smaller dam having a volume of approximately 3-4 ML. Review of survey information indicates that the existing embankment height is approximately 5m for the large dam, and some 3m for the smaller dam. No design details were available from the *Department of Soil Conservation* (pers. Garry Brown, Dept. of Lands, Singleton), however Mr Brown indicated that the method of construction followed standard Soil Conservation Service guidelines, including the stripping of topsoil and unsuitable subsoil down to a clay foundation, the creation of an embankment using clay subsoil materials (*he noted that there was no roller compaction of the embankment*), and that the clay soils were dispersive in nature, and would have been treated with the addition of gypsum for stabilization. Mr Brown went on to indicate that the dam would have been provided with an appropriately sized and graded spillway, with adequate freeboard to prevent the main embankment overtopping during major storm events.

- Based on the records of construction (*provided verbally by Mr Brown at this stage – Worley Parsons is currently seeking documented records from Lands*), it can be stated that while the dam embankment construction seems reasonable for a farm dam, it is not considered to be of optimum design, such as would be adopted for a detention basin within a residential area, in that only rudimentary compaction of the embankment has been undertaken using track-rolling with a Dozer, and the addition of a nominal amount of gypsum for stabilization. Certainly no guarantees can be made regarding the long term viability of the embankment against potential piping failure, or overtopping failure during large storm events, through eventual erosion of the dam embankment and / or spillway.

- Given the above, it is our opinion that the landowner would need to continue to maintain the existing farm dam to the satisfaction of the *Department of Water and Energy* and Council, however, we also believe that the proposed development should allow for the potential for a dam failure in determining the corridor widths allowed for in the rezoning study.

- An analysis of the main dam on Mr Foggo's property indicates that a dam breach could possibly generate a peak dambreak discharge of up to 56 m^3/s from the main dam (*refer **Attachment B***). We note however, given the limited volume of the dam (*up to 20 ML*), the volume of the discharge hydrograph would be limited to 20ML, and therefore, the peak dambreak discharge of 56 m^3/s would be quickly attenuated within the downstream tributary reach and Limestone Creek, given the available flood storage and roughness within the proposed rehabilitated stream. However, in order to be conservative at this stage, we have run this full peak discharge through the entire reach of the existing hydraulic model to determine the potential flood extent from such a scenario, compared to the proposed development boundaries.

- For the smaller dam, a peak dambreak discharge of some 6.5 m^3/s was estimated (refer **Attachment B**), this level of discharge is believed to be able to be controlled within an 8m wide corridor adjacent to a planned roadway within the development area. This is indicated in **Figure 2**.

- **Figure 1** attached shows the flood profiles for the Limestone Creek Tributary, and the upper extent of Limestone Creek for both the 100 year ARI flood event in Limestone Creek, and the proposed dam break scenario, as well as the 100 year ARI event including 500mm freeboard (*above which all habitable property floor levels property would be developed*). It is noted that the potential peak dam break flow (*56 m^3/s*) is less than the predicted 100 year flow in the lower reaches of Limestone Creek (*67m^3/s*). Hence, the 100 year flood would be the dominant flood scenario in the lower reaches of Limestone Creek.
- **Figure 2** indicates the predicted flood extents for a dam break scenario in the Limestone Creek Tributary. Despite the potential peak flow from a dam break scenario being significantly higher than the 100 year flow through the tributary, hydraulic modeling indicates that the predicted dambreak flood extent would be contained within the existing riparian corridor. This is due to the steep gullied nature of the tributary. The existing riparian corridor is to be maintained under the development proposal and is proposed to be zoned 6(a) open space.
- Given the above, it is considered that the existing farm dams within Mr Foggo's lands can be maintained without impacting on the rezoning plan as exhibited, provided the landowner maintains the dams in a reasonable condition to the satisfaction of DWE and Council. Periodic inspection of the dams by qualified engineers is recommended (*say 12 monthly*) to ensure the dam embankments do not fall below an acceptable level of maintenance. In addition, the greatest perceived risk is for a sudden "sunny day" type failure, whereby even without rainfall in the catchment, that might warn persons of an impending flood within Limestone Creek, a dam failure could occur due to a piping failure through the earth embankment, leading to the sudden failure of the dam wall. Such a failure scenario should be planned against, in the allocation of suitable zoning of flood prone lands (as per the current proposal), and the appropriate treatment of the creeklines through dense, re-vegetation to limit public access to Limestone Creek, and the placement of appropriate floodway signage warning current and future residents of the potential for a sudden rise in flood waters within the creeklines.

Development within the 100 year Flood Extents in the Ruby Street Area

Council has advised that local residents are concerned that the proposed filling of low lying areas at the end of Kalingo Street, and adjacent to Ruby Street could exacerbate existing flooding problems in the area.

It is estimated that a peak 100 year flow in the Ruby Street area is approximately 40 to 50 m^3/s (*a small tributary entering Bellbird Creek upstream of the Hetton Street bridge contributes approximately 10m^3/s*). The existing Bellbird Creek channel is estimated to have a capacity ranging between 20m^3/s to 40 m^3/s depending on the location. The existing bridge crossings are generally undersized for large flood events and in some areas development is directly adjacent to the channel, creating channel constrictions. Accordingly, it is estimated that there would be approximately 20 to 25 m^3/s of out of channel flow during a 100 year flood event. This flow is expected to principally flow down both Kalingo and Ruby Streets, but also between existing properties. It is imperative that this flood conveyance down these road reserves is maintained in order to not adversely influence flood behavior in the existing residential area. The expected flood behavior is schematically illustrated in **Figure 3**. Note: the reported flows in **Figure 3** are relatively conservative estimates based on model results and review of survey information. Further assessment is required, as part of any future development application, to verify the reported flows and ensure mitigation measures are appropriately designed.

Recommended filling areas were selectively located outside of floodways, which were determined by HEC-RAS 1-D modeling. Accordingly, it is expected that the proposed filling would not adversely impact flood behavior affecting local residential areas as long as conveyance down both Kalingo and Ruby Streets is maintained. This would be achieved by:

- Not filling at the end of Kalingo Street, in order to allow any floodwater conveyed along the road reserve to freely discharge back into Bellbird Creek Channel (*as per existing conditions*). This was recommended in the rezoning strategy and subsequently the proposed development area was "pulled back" to not impede the existing overland flow path.
- Maintain the existing flood conveyance along Ruby Street by providing an appropriately sized road side swale to convey the expected flows past the proposed development area. This may require a road side swale to be constructed on the western side of Ruby Street (*as indicated in **Figure 3***).
- Any upgrade of the Abbotsford Street culverts and intersection would be undertaken in a manner which does not impede on existing flood conveyance along Ruby Street, Kalingo Street or the Bellbird Creek Channel.
- There is potential to improve the local flooding in the Abbotsford Street area by modifying the existing Abbotsford Street Bridge. This was discussed in the strategy.

In addition to excess flood flows in Bellbird Creek escaping the main channel in this area, there is potential for flooding to occur from stormwater runoff occurring from localised catchments (*i.e. not flooding from Bellbird Creek*). A locally defined subcatchment was identified to the south west of Prince Street. The total catchment extent was conservatively estimated to be 6.5ha (*refer to **Figure 3** for assumed catchment extents*). The resulting peak 100 year flow would be approximately 1 m^3/s. It is proposed to provide a piped drainage system capable of collecting and conveying the peak 100 year flow through the proposed development area. This concept is illustrated in **Figure 3**. Similarly, Ruby Street would have a stormwater system designed to capture and convey localised stormwater in addition to maintaining conveyance for the much larger Bellbird Creek flows, as described above.

Land Ownerships and Stormwater Management Basins

Council has previously expressed concern that the proposed stormwater management measures may be problematic considering the landownership issues and the development application processes.

With reference to **Table 5.2** in the stormwater flooding assessment, all stormwater management measures are defined on a per area of development basis (*i.e. 200m^2 of wetland area is required per ha of development area*). These measures would be applied to all residential areas within the study area. Accordingly, at the DA stage, when development staging plans have been determined, the proposed locations of stormwater management measures will require revision. The developer will be obliged to provide stormwater management measures in accordance with per hectare of development area requirements specified in **Table 5.2.** In some cases, this may require temporary basins.

Medium Density Zoning within the PMF flood extent

Council has previously stated that they do not normally grant medium density zoning within the Probable Maximum Flood (PMF) extents. Council has asked WorleyParsons to comment on the two areas within the masterplan where medium density zoning have been proposed within the PMF extent (refer attached **Figure 4**).

Reference to **Figure 4** indicates that there have been two nominated areas of medium density development proposed within the PMF flood extent. We note however that the northern medium density area (*i.e. on the northern bank of Limestone Creek*) would likely be inundated from the PMF only after floodwaters break out of the channel and flow in a south-easterly direction towards the Bellbird Creek floodplain. We therefore believe that while this northern area is within the PMF flood extent, the nature of flooding in this area during extreme events would be the backing up of floodwaters from the top of bank of the channel, rather than the over-topping release of floodwaters such as will occur on the southern side of Limestone Creek. That is to say, the flooding on the northern bank of Limestone Creek would likely be of low velocity, and therefore not of a particularly high hazard. In fact, it may be argued that multi-storey development within these areas (*i.e. low velocity out of bank flooding*) is preferable, in that it allows for a vertical escape route for persons within their own homes, in order to prevent loss of life. We note however, that it is preferable that these area be fully evacuated, rather than rely on a vertical evacuation strategy as the first preference.

The proposed smaller section of medium density residential development on the immediate southern side of Limestone Creek should most probably be relocated to an area of lesser risk, either outside of the PMF flood extent, or rather to an area where floodwaters will not be directly spilling between Limestone Creek and the Bellbird Creek floodplain.

We trust that this letter addresses your request, please feel free to contact the undersigned on (02) 4928 7777 should you have any queries.

Yours faithfully

WorleyParsons

Ben Patterson
Manager, Infrastructure and Environment, Newcastle

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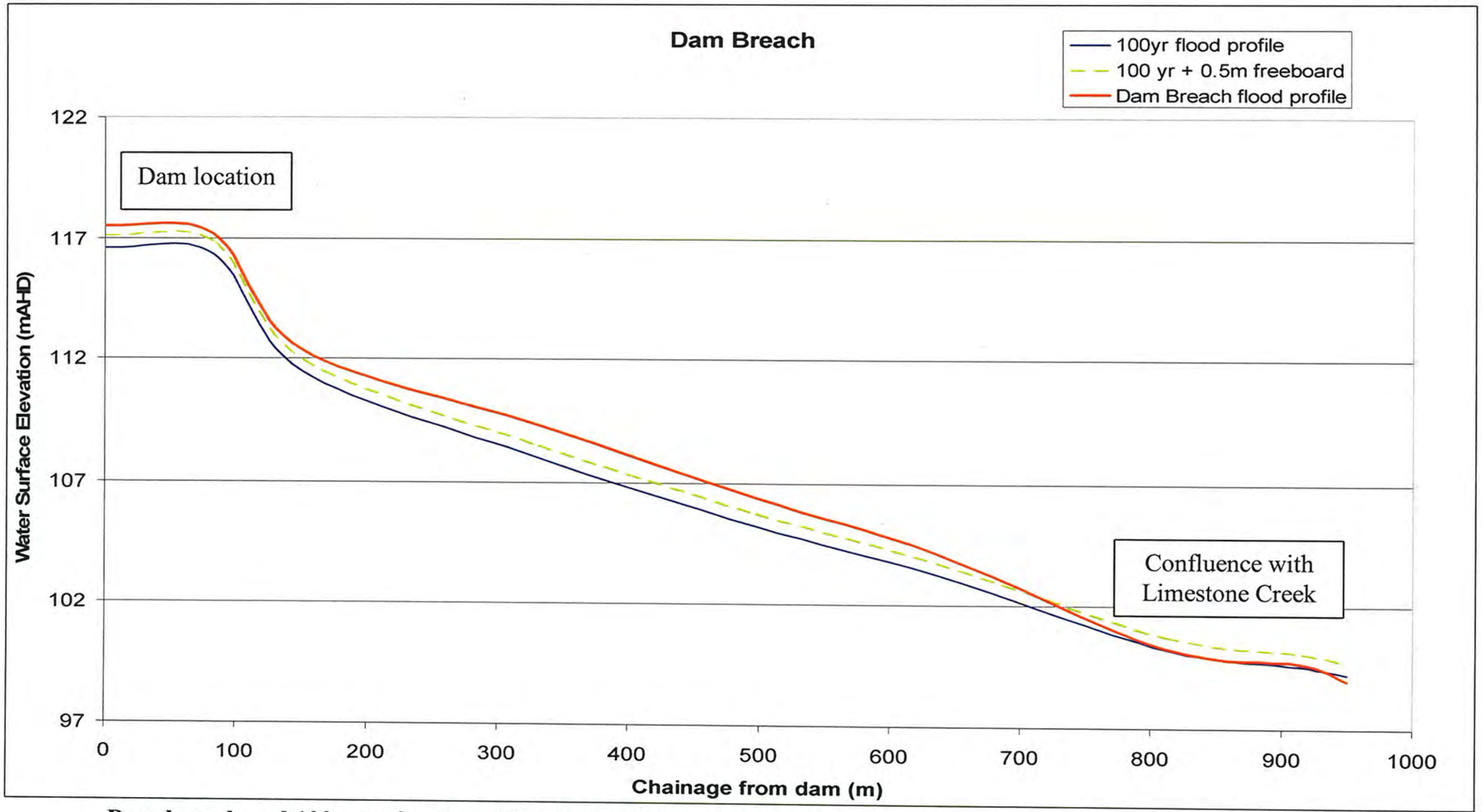
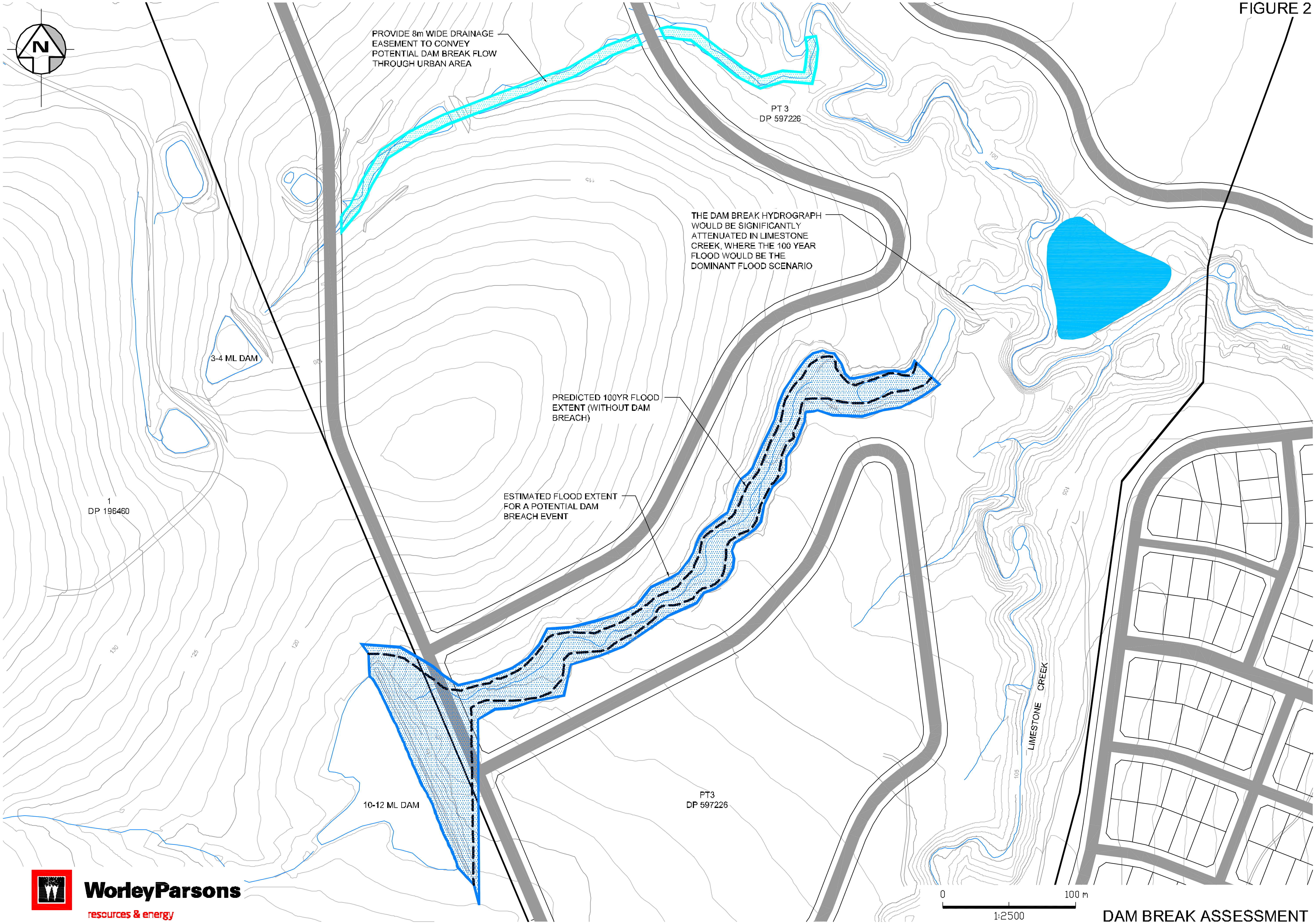
FIGURE 1



Dam breach and 100 year flood profiles along tributary to Limestone Creek

FIGURE 2



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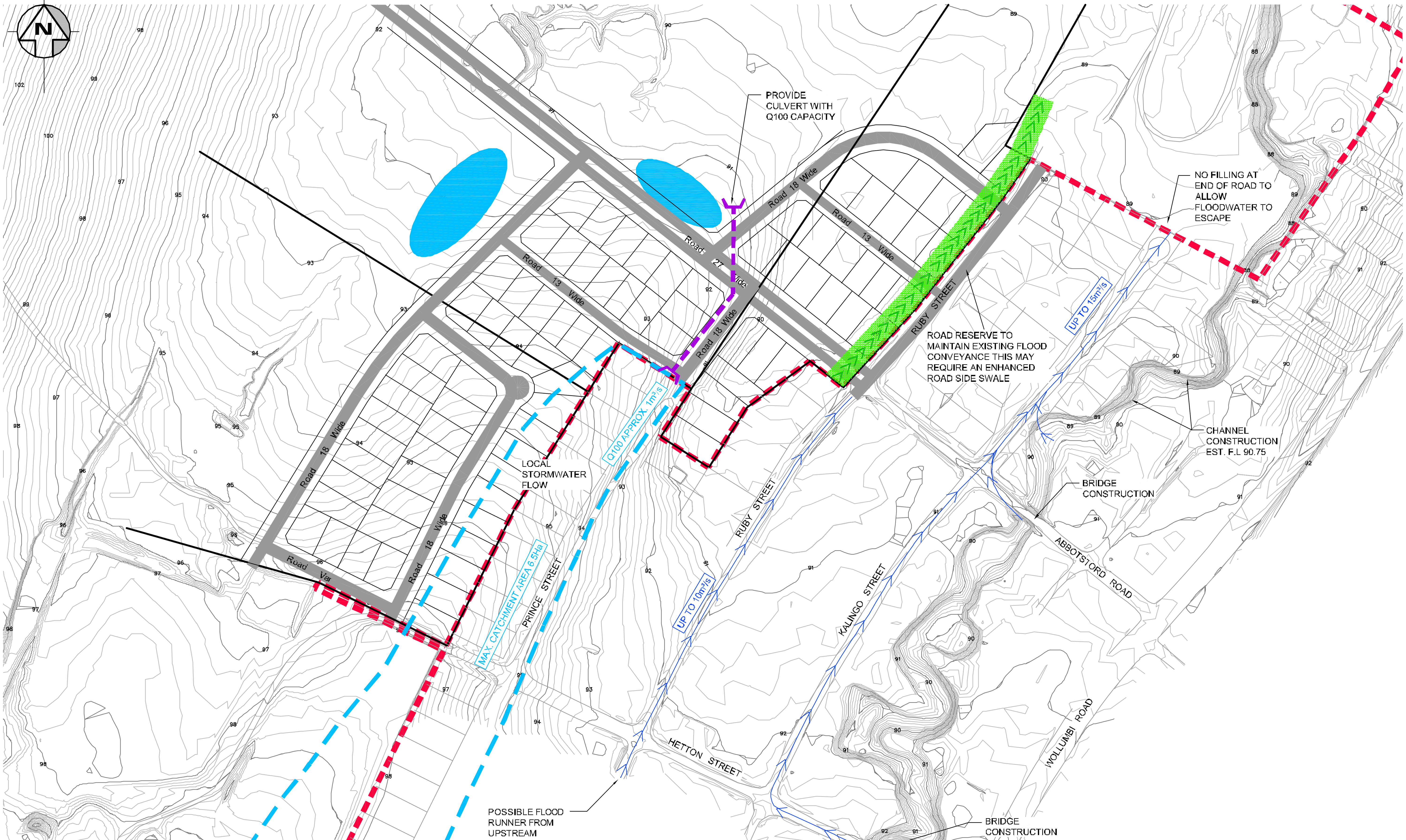
DAM BREAK ASSESSMENT

D:\6873.03 North Bellbird - 2D Flood Modelling (BP)\03_Data\CAD\FIG2_Dam Break Assessment.dwg 23/10/2008

FIGURE 3



NOTE:
REPORTED FLOWS ARE CONSERVATIVE ESTIMATES WHICH REQUIRE FURTHER ASSESSMENT TO VERIFY

0 100m
1:2500

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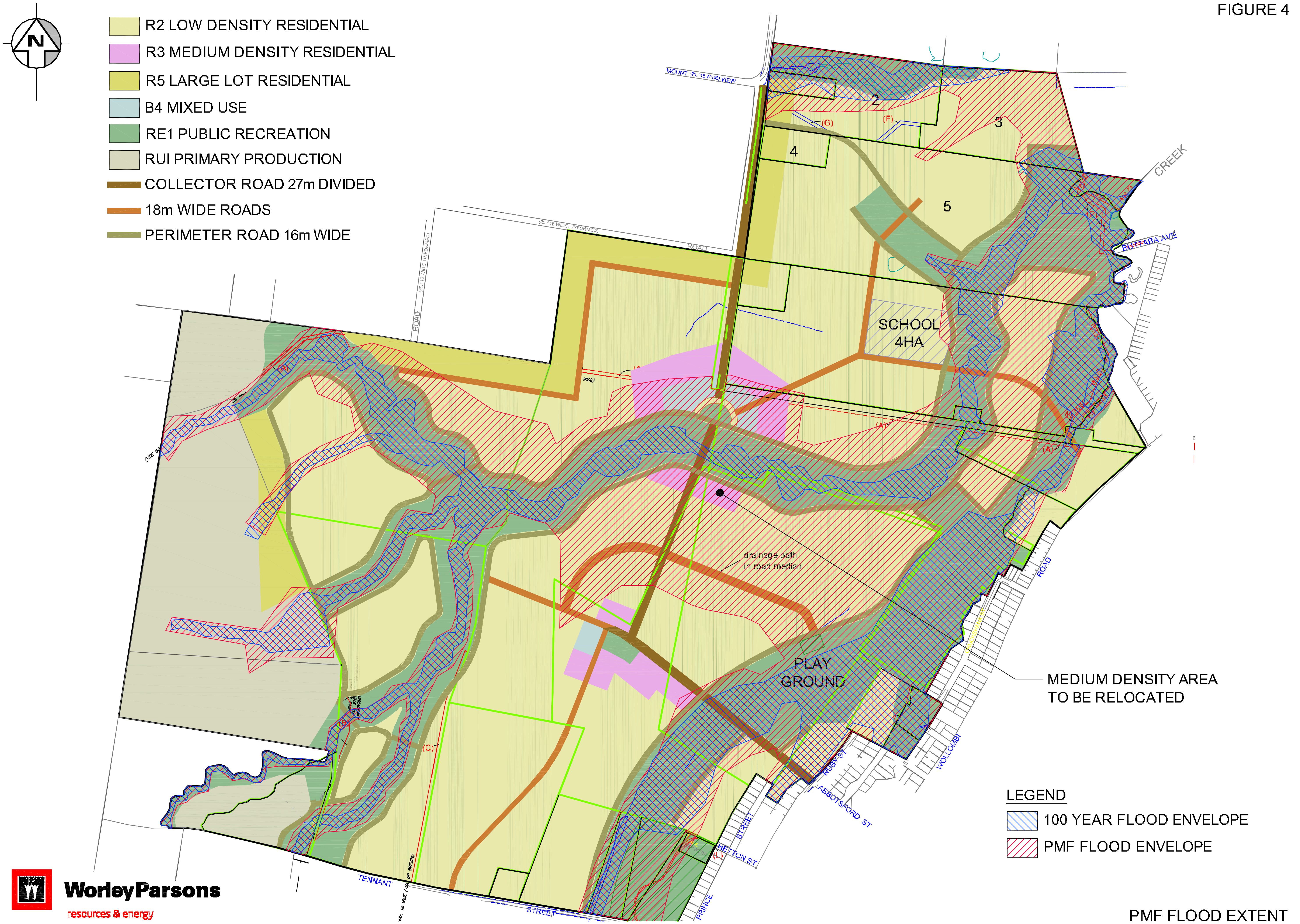
ESTIMATED OVERLAND FLOWS

O:\6873.03 North Bellbird – 2D Flood Modelling (BP)\03_Data\CAD\FIG3_Estimated Overland Flows.dwg 23/10/2008

FIGURE 4



PMF FLOOD EXTENT

O:\6873.03 North Bellbird - 2D Flood Modelling (BP)\03_Data\CAD\FIG4_PMF Flood Extent.dwg 28/10/2008

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Attachment A- Advice from the Department of Lands

The Department of Land and Water Conservation incorporates the former Departments of Conservation and Land Management and Water Resources

FAXED 1/6/94

Mr Robert FOGGO
15 High St.
NEWCASTLE 2300

CALM
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
1 Civic Ave. [redacted]
Singleton NSW 2330
Phone (065) 72 1707
Fax (065) 72 1592

RE: PROPOSED DAMS ON PROPERTY AT CESSNOCK

Dear Robert,

Sorry for the delay in getting back to you with a cost to construct the dams on your property a Cessnock.

Since my inspection of the property with you I have taken levels on the large dam site I suggested and also ran levels over a potential dam site immediately above the boundary where we looked at the erosion along the fence.

This site is on the main flowline below the site I suggested to you. The levels indicate this lower site to be better than the site I suggested further up the fowline. The lower site will allow for the construction of a dam with a storage capacity of about 10-12 megalitre. This site has the advantage. of a larger catchment area with the two hollows feeding it so no catchment drains will have to be constructed. There is one disadvantage to this site in that a number to trees will have to be removed. However in constructing the dam the erosion along the fence will be controlled and rehabilitated. The wall will be about 120 metres in length crossing both depressions and the old existing dam will be eliminated. The cost to construct this dam is similar to the other site but with greater storage capacity.

The results of the test from the soil sample I took indicate there may be a potential problem in sealing the dam. However only one sample was taken from the gully and at a relatively shallow depth (about 1m). There are other dams in the area both in the neighbours above and below that hold water. I do not think there will be a problem however as a precaution during construction I suggest samples be taken and analysed to check the material at depth.

If there is a problem an ameiorant can be added to the excavation once the dam has been constructed. This will add $1,200.00 to the cost.

Cost to construct the dams:-

-	Large dam 10-12 mgealitre this includes soil testing	$12,000
	Ameliorant STPP if needed	1,200
–	Small dam in hollow below house	3,000

Cost to build the dams if material tests to be suitable is $15,000. If material requires treatment the cost will increase by $1,200.00 to a total cost of $16,200.00.

We have machinery working in the area and will be available upon completing the present job in 3-4 weeks; three weeks if there are no hold ups due to the weather.

If you wish to inspect the new site please contact me to arrange a time.

Please notify me as to your intention to proceed with construction of the dams and I will forward you our standard contract for signature and to be return to me along with a 25% deposit before commencing work. To assist me in completing the contract I need details of the property ie. Lot/DP/Portion and Parish numbers.

If there are any questions or you require further information please do not hesitate to contact me.

Yours faithfully,

J.A. (John) Hindmarsh
DISTRICT SOIL CONSERVATIONIST
SINGLETON

1 June, 1995


'95 1 15

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Attachment B- Dam Design Break Calculations

NWS SIMPLE DAM BREAK EQUATION:

Your Small Dam

$$Q_b = Q_o + 3.1B_r(C/(T_f + C/\sqrt{H}))^3$$

WHERE,

Q_b = BREACH FLOW + NON-BREACH FLOW (cfs)
Qo = NON-BREACH FLOW (cfs)
Br = FINAL AVERAGE BREACH WIDTH (ft, APPROX. 1H TO 5H)
C = 23.4*As/Br
As = RESERVOIR SURFACE AREA (ac) AT MAXIMUM POOL LEVEL
H = SELECTED FAILURE DEPTH (ft) ABOVE FINAL BREACH ELEVATION
T_f = TIME TO FAILURE (hrs, USE H/120 OR A MINIMUM OF 10 MIN)

INPUT VARIABLES:

Qo =	**0**	**cfs**
As =	**0.40**	**ac**
H =	**6.8**	**ft**

Note: Must enter Data on Brwidth Worksheet as well

OUTPUT VARIABLES:

	SELECTED BREACH WIDTHS Br, [ft]	TIME OF FAILURE T_f, [hrs]	COMPUTED C VALUE	MAXIMUM BREACH FLOW Q_b, [cfs]	
6.8	[H]	0.17	1.38	**162**	**5.99**
10.2	[1.5H]	0.17	0.92	**172**	**6.37**
13.6	[2H]	0.17	0.69	**168**	**6.23**
17.0	[2.5H]	0.17	0.55	**159**	**5.88**
20.4	[3H]	0.17	0.46	**148**	**5.46**
23.8	[3.5H]	0.17	0.39	**136**	**5.03**
27.2	[4.0H]	0.17	0.34	**125**	**4.62**
34.0	[5.0H]	0.17	0.28	**105**	**3.89**
14.8	Froelich Eq	0.19	0.63	**145**	**5.38**
14.8	Froelich Eq	0.17	----	**231**	= Volume / Failure tim

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BREACH PREDICTOR EQUATIONS

Recently some statistically derived predictors for average breach width (b) and time of failure (T_f) have been developed by MacDonald and Langridge-Monopolis (1984) and Froelich (1987, 1995). From Froelich's work in which he used the properties of 63 breaches of dams ranging in height from 12 to 285 feet, with 6 dams greater than 100 feet, the following predictor equations were obtained:

$$T_f = 0.59(V_s^{0.47})/(H^{0.91})$$

$$b = 9.5 K_o (V_s H)^{0.25}$$

where,

b = average breach width (ft),
T_f = time of failure (hrs), only includes vertical erosion of dam
K_o = 0.7 for piping and 1.0 for overtopping failure
Vs = storage volume (ac-ft), and
H = height (ft) of water over breach bottom

BREACH WIDTH & TIME OF FAILURE FOR

Your Small Dam

INPUT VARIABLES:			OUTPUT PARAMETERS:		
H =	6.80	ft	b =	14.8	ft
Vs =	3.6	ac-ft	T_f =	0.19	hrs
Ko =	0.7				

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NWS SIMPLE DAM BREAK EQUATION:

Your Small Dam

$$Q_b = Q_o + 3.1B_r(C/(T_f + C/\sqrt{H}))^3$$

WHERE,

Q_b = BREACH FLOW + NON-BREACH FLOW (cfs)
Qo = NON-BREACH FLOW (cfs)
Br = FINAL AVERAGE BREACH WIDTH (ft, APPROX. 1H TO 5H)
C = 23.4*As/Br
As = RESERVOIR SURFACE AREA (ac) AT MAXIMUM POOL LEVEL
H = SELECTED FAILURE DEPTH (ft) ABOVE FINAL BREACH ELEVATION
T_f = TIME TO FAILURE (hrs, USE H/120 OR A MINIMUM OF 10 MIN)

INPUT VARIABLES:

Qo =	0	cfs
As =	2.20	ac
H =	11.0	ft

Note: Must enter Data on Brwidth Worksheet as well

OUTPUT VARIABLES:

	SELECTED BREACH WIDTHS Br, [ft]	TIME OF FAILURE T_f, [hrs]	COMPUTED C VALUE	MAXIMUM BREACH FLOW Q_b, [cfs]	
11.0	[H]	0.17	4.68	884	32.75460232
16.5	[1.5H]	0.17	3.12	1134	41.98916918
22.0	[2H]	0.17	2.34	1302	48.22201412
27.5	[2.5H]	0.17	1.87	1412	52.28754897
33.0	[3H]	0.17	1.56	1479	54.77946184
38.5	[3.5H]	0.17	1.34	1515	56.12494909
44.0	[4.0H]	0.17	1.17	1529	56.63442876
55.0	[5.0H]	0.17	0.94	1512	55.99566066
24.9	Froelich Eq	0.26	2.06	993	36.79456153
24.9	Froelich Eq	0.17	----	841	= Volume / Failure tim

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BREACH PREDICTOR EQUATIONS

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where,

b = average breach width (ft),
T_f = time of failure (hrs), only includes vertical erosion of dam
K_o = 0.7 for piping and 1.0 for overtopping failure
Vs = storage volume (ac-ft), and
H = height (ft) of water over breach bottom

BREACH WIDTH & TIME OF FAILURE FOR

Your Small Dam

INPUT VARIABLES:		OUTPUT PARAMETERS:	
H =	11.00 ft	b =	24.9 ft
Vs =	18.0 ac-ft	T_f =	0.26 hrs
Ko =	0.7		

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