BMT WBM

Cumbalum Ridge: Inundation Investigation for Ballina Nature Reserve and Adjacent Properties

R.B19181.001.01 **December 2012**

ballina shire council

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Title :	Inundation Investigation for Cumbalum Ridge and Ballina Nature Reserve
Author :	Cathie Barton, Ben Caddis and Chris Nielsen
Synopsis :	Investigation of variation in spatial and temporal inundation patterns for wet and dry years across the Ballina Nature Reserve and adjacent properties. The potential impacts of Cumbalum Urban Release Area (CURA) on these inundation patterns has been estimated.

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1 INTRODUCTION

BMT WBM has undertaken investigations to estimate potential changes to inundation patterns across the Ballina Nature Reserve (BNR) wetlands and adjacent properties due to proposed residential development areas on Cumbalum Ridge (CURA – Cumbalum Urban Release Area). The location of the two proposed CURA precincts (A and B) are shown in Figure 1-1.

Existing residents downstream from Cumbalum Ridge have noticed changes to patterns of inundation (both temporal and spatial) across their properties in recent years. BMT WBM (in consultation with Ballina Shire Council (Council)) has discussed these issues with the concerned residents. Site visits to some properties have also been undertaken to assist in understanding current and past flow and inundation behaviour.

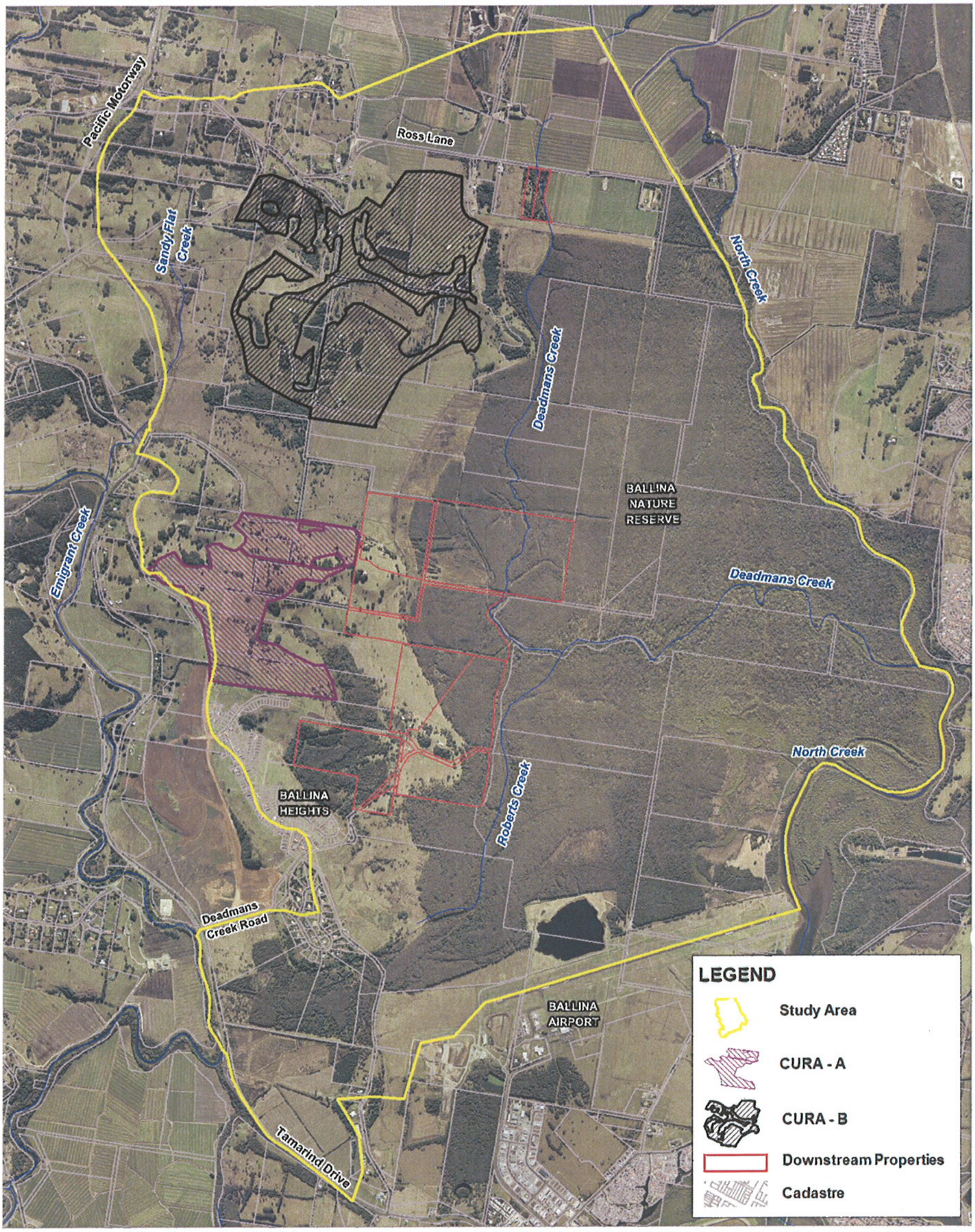
This assessment has been undertaken using a MUSIC model and a TUFLOW-GPU model. Long-term rainfall records have also been investigated to provide some indication of changes to the natural hydrologic regime over recent years.

1.1 Objectives

The objective is to estimate the potential impacts of the proposed CURA precinct developments on inundation patterns and timing through the BNR and adjacent properties. In order to meet this objective, the following scenarios were modelled:

1. Existing Development Base Case;
2. CURA Precinct A;
3. CURA Precinct B;
4. CURA A + B; and
5. CURA A + B + projected sea level rise.

Each of these scenarios was simulated for a 8 month period (October to May wet season) for a representative wet year and a representative dry year.



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Study Area and Locality

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1.2 Methodology

1.2.1 Background Data Compilation & Investigation

The following information was obtained for the purpose of the investigation:

- Rainfall – long-term rainfall records from both Ballina Airport AWS (058198) and Alstonville Tropical Fruit Station (058131) were collected and assessed.
- Low Flow Records – short-term low flow records at v-notch weir sites, from Ardill Payne and Partners.
- Water Level Records – water levels were recorded by BMT WBM at the confluence between Roberts Creek and Deadmans Creek for the period between 21 January 2012 and 21 March 2012.
- Tidal Boundaries at Missingham Bridge from MHL.
- Digital terrain data – used to determine catchment areas, hydraulic characteristics and parameters.
- Existing models – previous MUSIC modelling work undertaken by Ardill Payne for the CURA-A development.
- Information on density and location of proposed development within each CURA precinct.

1.2.2 Development Scenarios

There are two proposed precincts within the Cumbalum Urban Release Area (CURA). These are referred to as CURA-A and CURA-B. The locations of these precincts are shown in Figure 1-1.

Further details on CURA-A are contained within the reports by Ardill Payne and Partners (APP, 2012). The current investigation is focussed on predicting flow quantity (not quality) from the CURA-A and -B sites. However, the existing MUSIC model developed by APP (2012) for the CURA-A site is able to be used to provide the required flow volumes and timings. A MUSIC model (and output flows) is not available for the CURA-B site. To fill this gap, BMT WBM has developed a conceptual MUSIC model for CURA-B based heavily on the CURA-A model. The difference between these models is that the percentage impervious area is slightly higher for CURA-B; 42% compared to 32%, based on advice from Council that CURA-A is anticipated to have 11 dwellings per hectare and CURA-B to have 15-17 dwellings per hectare. More information on the MUSIC modelling is provided in subsequent sections.

1.2.3 Model Selection

A MIKE SHE numerical model was initially considered for use in this project. However, following preliminary development of this model, BMT WBM found that model outputs did not provide the correct resolution or context for the problem being assessed. Instead, the MUSIC model and the TUFLOW-GPU model were selected to work together to provide results required. These models are discussed further in the following sections. However, it is important to note that the TUFLOW-GPU model has been developed solely for the purpose described within this document. The focus of the TUFLOW-GPU model is in estimating changes to inundation patterns through the BNR and adjacent properties. While a calibration has been undertaken to low-flows, the model is not capable of predicting absolute water levels or velocities.

1.2.4 Model Setup and Calibration

Two models have been used to undertake the current investigation: MUSIC and TUFLOW-GPU. Discussion on these models follows.

MUSIC (Model for Urban Stormwater Improvement Conceptualisation). The MUSIC model was used to provide surface and baseflows from the catchment areas over which development is proposed for entry into the TUFLOW model. BMT WBM planned to utilise the MUSIC model developed across the CURA-A precinct by Ardill Payne and Partners (APP, 2012). APP provided this MUSIC model to BMT WBM to assist in the current investigation. BMT WBM reviewed the suitability of this model in providing flows (not water quality values) for the purpose of assessing flows to the BNR and adjoining private land. The following points are an important outcome of the review:

- The APP MUSIC model was developed in Version 4 of the MUSIC model software. Since completion of the model by APP, Version 5 of the software was released. Version 5 contains new features that are now available, that were not available to APP at the time of model development. These new features have enabled us to assess some of the flow volume outputs.
- The APP MUSIC model has exfiltration parameters that result in a net loss of water to the system. Due to the use of Version 4, APP would not have been able to easily assess this loss.
- As the purpose of the current investigation is solely related to flow volumes from the development site (not water quality values), it is important that net loss of water to the system does not occur. As such, BMT WBM set the exfiltration parameters in the APP MUSIC model to zero. This resulted in an increase in cumulative flow volumes when compared to the original APP MUSIC model.
- Following this change, we believe that the modified APP MUSIC model provides flows that are considered it to be appropriate for the purpose of this study.
- Due to the change in the predicted flow volumes occurring with the change in the exfiltration parameter, the APP model may benefit from a detailed review, as the design of the system may be impacted by this change. This is outside the scope of this current investigation. In addition, the APP report indicates that simple water quality and flow devices were used in the model at the request of Council to minimise longer-term maintenance issues. The review may also provide advice on best-practice devices not currently being considered.

As mentioned in Section 1.2.2, BMT WBM also developed a CURA-B MUSIC model that is based heavily upon the modified CURA-A model. While the CURA-B model satisfies the requirements of estimating flow volumes from the CURA-B site, it is not fit for any other purpose and should not be used beyond the bounds of the current study. BMT WBM also developed an existing (pre-CURA-development) MUSIC model to provide existing flows over the CURA-A and CURA-B catchments.

TUFLOW-GPU (Two-dimensional Unsteady Flow Hydrodynamic Model) using GPU (Graphical Processing Unit) capabilities. The TUFLOW-CPU model is a 2D numerical model typically used in flood applications where simulations are confined to a single storm / flood event. In the case of the current investigation at Cumbalum, the 'event' of interest is the long-term wetting and drying of the Ballina Nature Reserve and adjacent private properties. Thus, the temporal scale is of the event is of the order of years rather than days. Simulation of such a long temporal scale is not possible in the TUFLOW-CPU model (the 'classic' version of TUFLOW as used for flood impact modelling in and around Ballina), but does become more reasonable in a TUFLOW-GPU model. The reason for this is that the model software is structured such that it is able to utilise the GPU to increase the speed of model simulations. A TUFLOW-GPU model has been developed across the BNR and around the Cumbalum Ridge for the purpose of this study.

Low flow outputs from the existing case MUSIC model were calibrated to the low flow record at the V1 v-notch weir site. Very low flows have been derived at the weir site from March 2011 by APP. Further discussion on the derived flows is contained in Section 2.2.3. Peak flow records do not exist in this area and calibration to the higher flows was not possible.

Following low flow calibration, flows originating from the Cumbalum Ridge catchments were estimated using the calibrated MUSIC model. These flows formed the upstream boundary conditions for the TUFLOW-GPU model. Rainfall and evapotranspiration (ET) losses across the 2D model domain are input as direct rainfall minus ET on the model grid.

A TUFLOW-GPU grid resolution of 20m was used across the 2D model domain. This resolution was chosen as it provides sufficient definition of the terrain (within the limit of accuracy of the DEM) and realistic run times.

1.2.5 Model Simulations

Simulations have been undertaken for each of the scenarios described in Section 1.1 for a 8 month period (September to May wet season) for a representative wet year and a representative dry year. That is, the MUSIC and TUFLOW-GPU model were run for two simulation periods of 8 months each. The representative wet year wet season assessed was October 2011 to May 2012 (inclusive) and the representative dry year wet season was October 2003 to May 2004 (inclusive). These 8 month periods were chosen as they represent the complete wet season across these representative years and yet result in manageable TUFLOW-GPS model run times.

1.2.6 Impact Assessment

Spatial and temporal output from the TUFLOW-GPU model was used to estimate the changes to the period of inundation across the full domain of the model. This was achieved by using model outputs to calculate the period of inundation for each 2D model cell and then subtracting the periods to obtain an impact or difference. Table 3-1 contains a summary of impact scenarios assessed and results are presented in Section 3.3.

1.2.7 Mitigation

Mitigation of the impacts of the CURA developments on water quality or quantity is not an objective of this investigation. As BMT WBM have been able to use the APP MUSIC model, it has been assumed that any mitigation and/or treatment devices proposed within this model are acceptable. However, as mentioned previously in Section 1.2.4, a revision of the MUSIC model may be beneficial for the following reasons:

- An update to the MUSIC software version has occurred since the APP model development,
- Recommended changes made by BMT WBM to the exfiltration parameter,
- Associated implications of these changes for the devices modelled, and
- Allows Council to consider whether higher-maintenance best practice devices are applicable.

2 BACKGROUND

2.1 Relevant Hydrologic Processes

Processes of the hydrological cycle of particular significance to drainage management (see Figure 2-1) include:

- Precipitation (Rainfall).
- Interception, Detention Storage and Evapotranspiration.
  - Interception is the process where precipitation is retained above the ground surface (mostly on vegetation), which then evaporates directly without adding to the soil moisture content.
  - Detention storage is surface water that is retained in depressions on the land surface and does not contribute to runoff.
  - Evapotranspiration is the combined process of evaporation from the land surface and transpiration from vegetation; these processes are generally not significant during intense rainfall events, and as such are usually not of major consequence to drainage management.
- Overland Flow.
  - Overland flow is the runoff of excess water over the ground surface. Flow typically accumulates as it flows downwards, forming streams and rivers. It is the mechanism that mostly causes flooding and inundation of land.
- Infiltration.
  - Infiltration is the passage of water from the land surface to the subsurface. This is dependent upon soil conductivity, soil moisture content and ground cover.
  - Urbanisation, which typically tends to cover the natural ground surface with concrete, bitumen, buildings, roads, etc, decreases infiltration rates. A low infiltration rate can result in more overland flow.
- Unsaturated Zone.
  - The unsaturated zone is defined as the subsurface region between the land surface and the groundwater table, where voids in the porous medium still contain air. The depth of the unsaturated zone varies as the groundwater table rises and falls.
- Saturated Zone.
  - The saturated zone is the subsurface below the groundwater table, where voids in the porous medium contain water. It can be conceptualised as a series of storages that transport water downstream. Interflow moves laterally through the subsurface with a faster response compared to groundwater, or baseflow. Flow in the saturated zone often emerges into streams, rivers and other water bodies.

Urbanisation of a catchment can change the hydrological response by reducing perviousness and increasing runoff response, creating more intense and shorter duration runoff events.

However, the principles of modern urban development and associated drainage design are intended to replicate the natural, un-developed state. Thus, a well-designed residential property development should have little or no influence upon the overall hydrological response of the catchment.

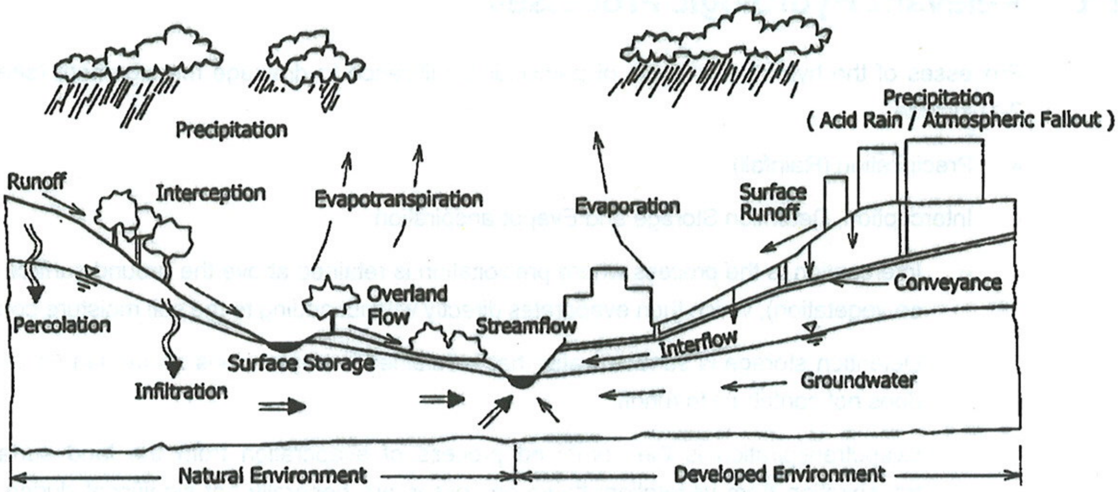


Figure 2-1 Hydrologic Processes

2.2 Relevant Hydrologic Data

2.2.1 Local Rainfall

Rainfall records are available at the Ballina AWS station (058198) for the period 1993 to 2012. This is a relative short-term period in terms of climate data. A longer period of record is available from the Alstonville Tropical Fruit Research Station (058131) for the period 1963 to 2011. The Mean Annual Rainfall (MAR) for water years (October to September) over the common period 1993 to 2011 is 1750mm and 1700mm for Ballina and Alstonville respectively. Figure 2-2 contains the variation in average monthly rainfall for both stations across the year. Figure 2-3 shows the variation of monthly rainfall statistics. These statistics indicate that the two stations record similar depths of average yearly and monthly rainfall with similar statistical distributions over the common period of record.

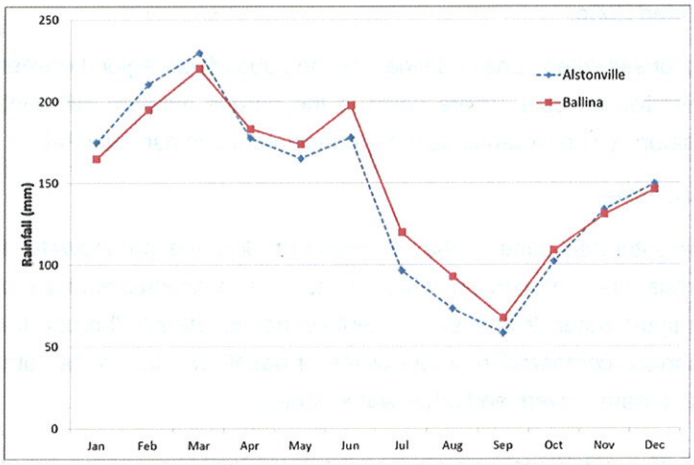
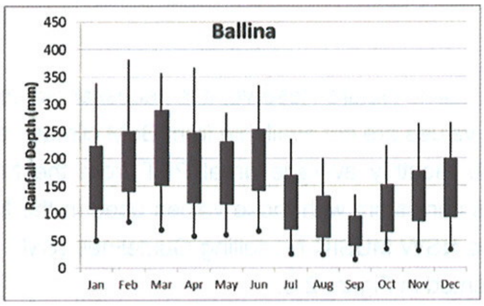
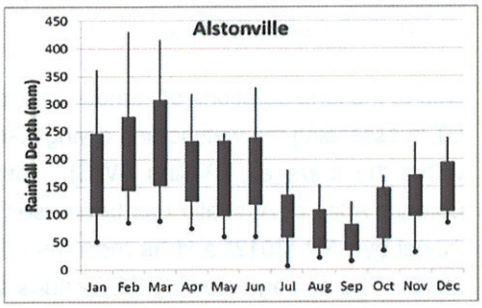


Figure 2-2 Variation in Average Monthly Rainfall (1993 to 2011)





Box = bounds of standard deviation | Top whisker = 90th Percentile | Bottom dot = 10th Percentile

Figure 2-3 Variation in Monthly Rainfall Statistics at Ballina and Alstonville (1993 to 2011)

Due to the proximity of the Ballina AWS Rain Gauge, the Ballina rainfall records are used to provide the necessary rainfall inputs to the MUSIC and TUFLOW-GPU models. However, the longer period of record at Alstonville allows us to consider the longer term variability in rainfall. Figure 2-4 shows the long-term variation in mean annual rainfall at Alstonville for the October to September water years. Rainfall records for the last 5 years (2008 to 2012) indicate total rainfall depths greater than the mean. The current assessment uses the wet seasons of the 2012 water year (October 2011 to September 2012) as the representative wet year and the 2004 water year (October 2003 to September 2004) as the representative dry year.

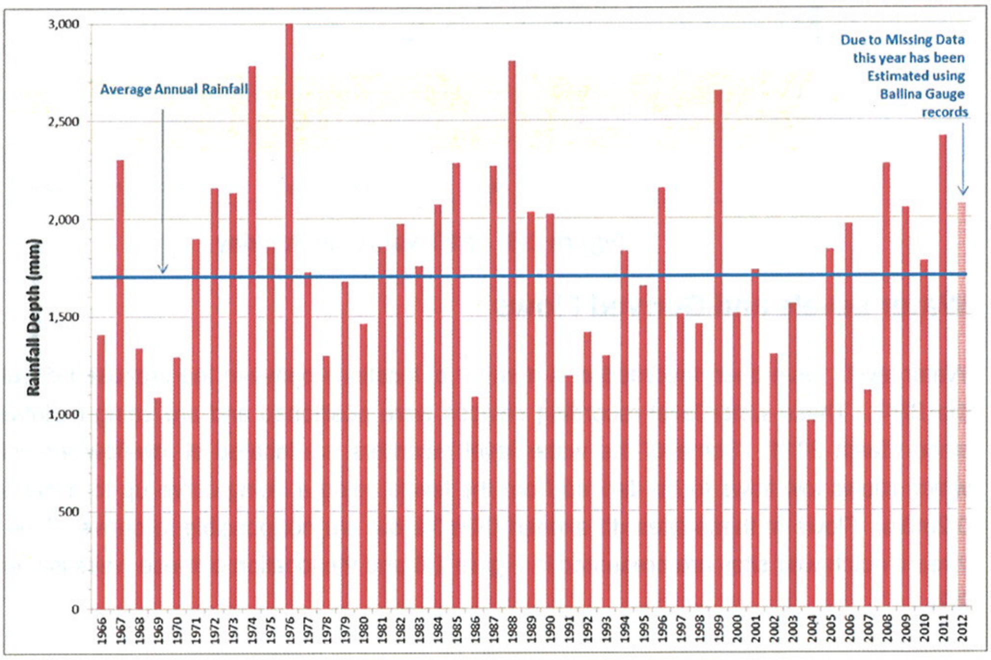


Figure 2-4 Variation in Mean Annual Rainfall at Alstonville (1966 to 2011 Water Years)

2.2.2 Evapotranspiration

Evapotranspiration (ET) describes the loss of water to the atmosphere due to evaporation from water surfaces and transpiration from plants. Being dependent upon factors such as temperature, wind and vegetation type, evapotranspiration rates vary spatially and temporally. Potential evapotranspiration (PET) is the amount of ET that would occur if there was sufficient water available. That is, PET is a measure of the atmospheric demand for water while actual ET is a measure of the water actually supplied to the atmosphere.

Due to the long durations of inundation across the Ballina Nature Reserve, it is necessary to consider ET in assessing the wetting and drying. Actual ET values are not available from BoM climate stations within the area (e.g. Ballina AWS). Instead, the monthly average areal PET from the National Climatic Atlas of Australia has been used. This is consistent with those values used in the MUSIC model by APP (2012) and as recommended in the NSW MUSIC Modelling Guidelines (BMT WBM, 2010). The average monthly PET values are presented in Figure 2-5.

These values have been applied to both MUSIC and TUFLOW-GPU. TUFLOW-GPU considers PET as a loss from each wet cell across the model. If the cell is dry or becomes dry, no loss is applied.

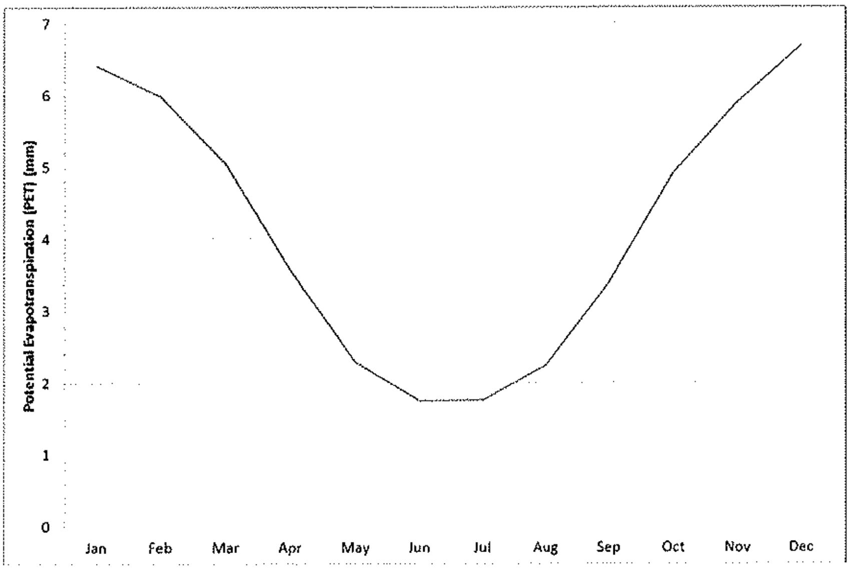


Figure 2-5 PET Values in mm/day

2.2.3 Water Levels and Derived Flows

Water levels have been recorded at a number of locations between the proposed development and the BNR. These water level recording devices were positioned and are being maintained by APP since March 2011. Some of the water level recorders are located at low-flow v-notch weir sites, which allows low flows to be derived from the levels using a rating curve up to a maximum flow of 0.2m3/s. Flows at these sites do exceed 0.2m3/s but are not possible to derive. Low flows at the three v-notch weir sites are presented in Figure 2-6 and the location of these weirs is shown in Figure 2-7.

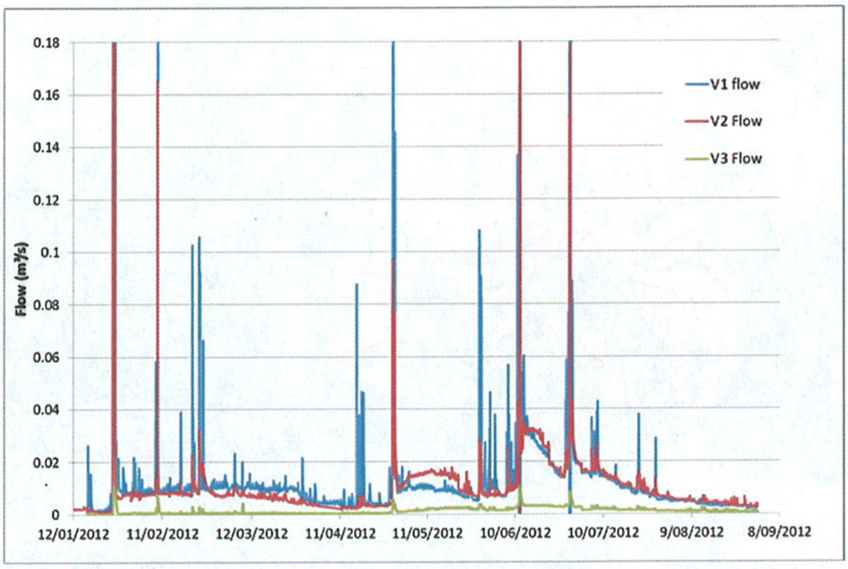


Figure 2-6 V-Notch Weir Flows

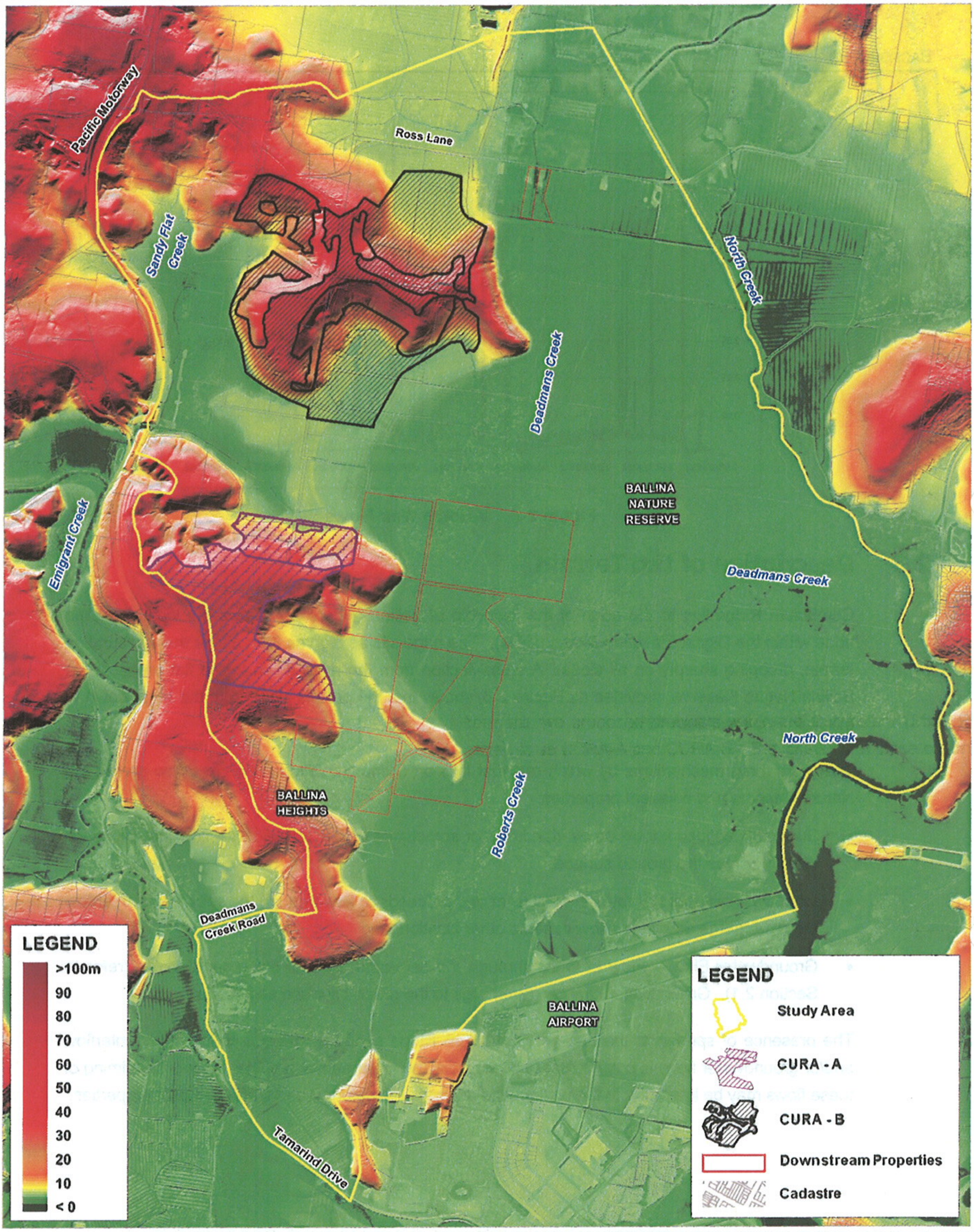
2.3 Description of the Terrain

Cumbalum Ridge lies to the north of the township of Ballina. Figure 2-7 shows the location of the ridge within the Digital Elevation Model (DEM). The ridge sits as high as 80m above the surrounding terrain, dropping sharply on all sides. A cross-section from the ridge down to the flat areas of the Ballina Nature Reserve, provided as Figure 2-8, shows that the ground slope from the ridge down to the plain is greater than 10%.

There are three mechanisms by which rain that falls on Cumbalum Ridge becomes flow across the Nature Reserve and adjacent properties:

- Surface flow (also known as overland flow or sometimes called 'quickflow') – flow that proceeds directly across the ground surface;
- Interflow – rain that infiltrates the soil layer and proceeds to flow through the soil matrix. Interflow may re-emerge as surface flow at some other location; and
- Groundwater Flow – Flow of water through the saturated zone of the ground profile (refer to Section 2.1). Groundwater flow can re-emerge to the ground surface as baseflow.

The presence of springs at the base of Cumbalum Ridge confirms that sub-surface flow (interflow and/or groundwater flow) is contributing to flow across the lower sections of the region. The timing of these flows may be important to the wetting and drying of the nature reserve and adjacent properties.



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Digital Elevation Model

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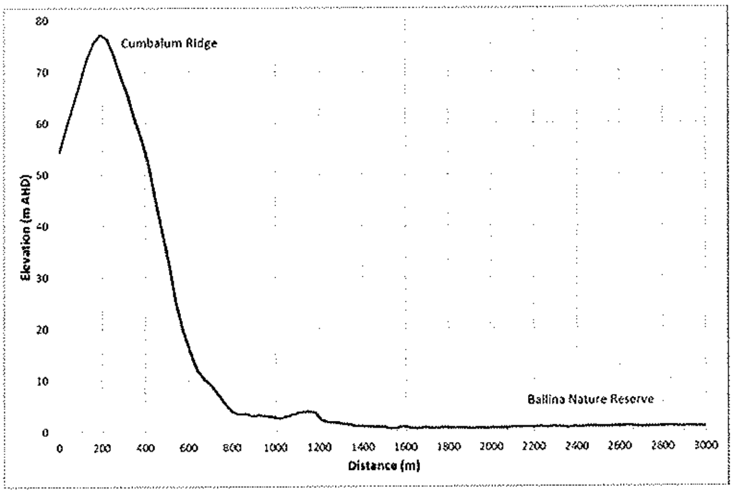


Location of Elevation Section shown in Figure 2-8

Figure 2-8 Elevation Section across Cumbalum Ridge and Ballina Nature Reserve

2.4 Sea Level Rise

Council has requested that the impact of a rising sea level will be assessed by considering the combined development scenario (CURA-A + CURA-B) in conjunction with the 2100 projected sea level rise of 0.9m.

3 MODELLING

Background methodology on model selection, calibration and simulation is contained in Section 1.2.

3.1 Model Setup

3.1.1 MUSIC

APP (2012) developed a MUSIC model for the CURA-A proposed development. This MUSIC model was developed to assist in the planning and design of stormwater management systems for the CURA-A site. BMT WBM have modified the APP CURA-A MUSIC model as described in Section 1.2.4 to provide necessary flows for this assessment. In addition, BMT WBM has developed two new MUSIC models for the current investigation: an existing case model and a CURA-B proposed development model. Further details on the information available and assumptions made in the development of these models are provided in Section 1.2.2 and Section 1.2.4.

Overland flow and baseflow outputs from these MUSIC models were used to provide flow inputs to the TUFLOW-GPU model from the relevant sub-catchments.

3.1.2 TUFLOW-GPU

A new TUFLOW-GPU model has been developed across the areas receiving flows from the proposed CURA-A and CURA-B sites. That is, all areas of interest outside the proposed development areas are covered by the TUFLOW-GPU 2D domain. The extent of the modelled area is depicted by the study area boundary in Figure 2-7.

Flows from the portions of the catchment covered by the MUSIC model are input to the TUFLOW-GPU model as a flow boundary condition. Direct rainfall is applied to all other areas within the 2D model domain. As discussed in Section 2.2.2, evapotranspiration losses were applied across the wet cells of the 2D model.

3.2 Model Calibration

The low flows from the existing case MUSIC model were calibrated to the V1 v-notch weir derived flow records. A comparison of modelled and derived flows is shown in Figure 3-1, and a zoom of the same data shown in Figure 3-2. This calibration focussed on the low flow behaviour following a rainfall event (recession shape of the hydrograph) and gave some confidence that the MUSIC model was able to produce low flows of the accuracy sufficient for the purpose of this investigation.

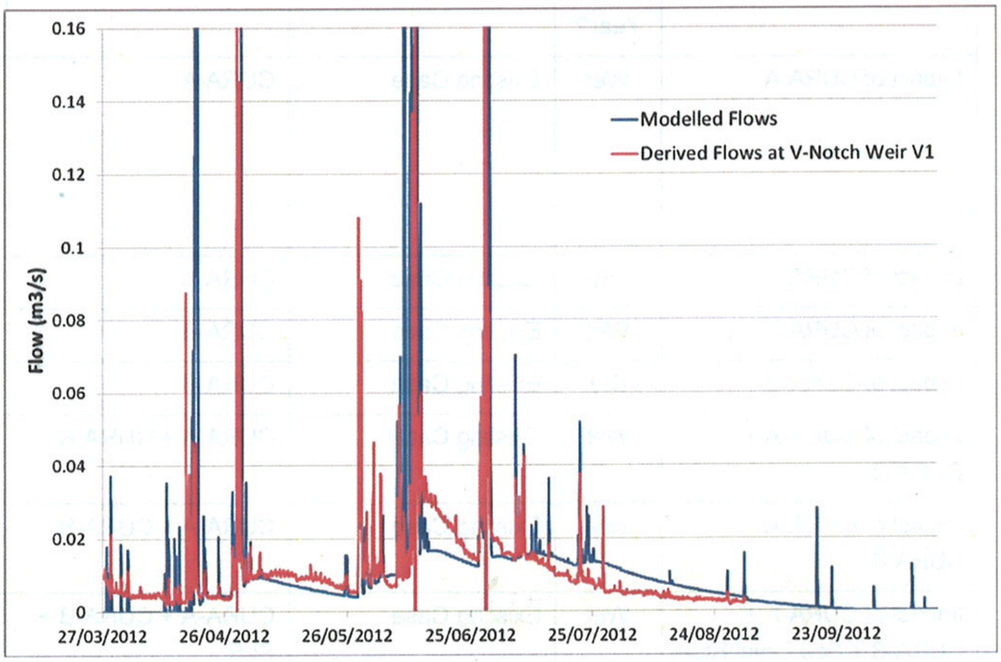


Figure 3-1 Comparison of Low Flows – Modelled versus Derived at V1 Low Flow Weir

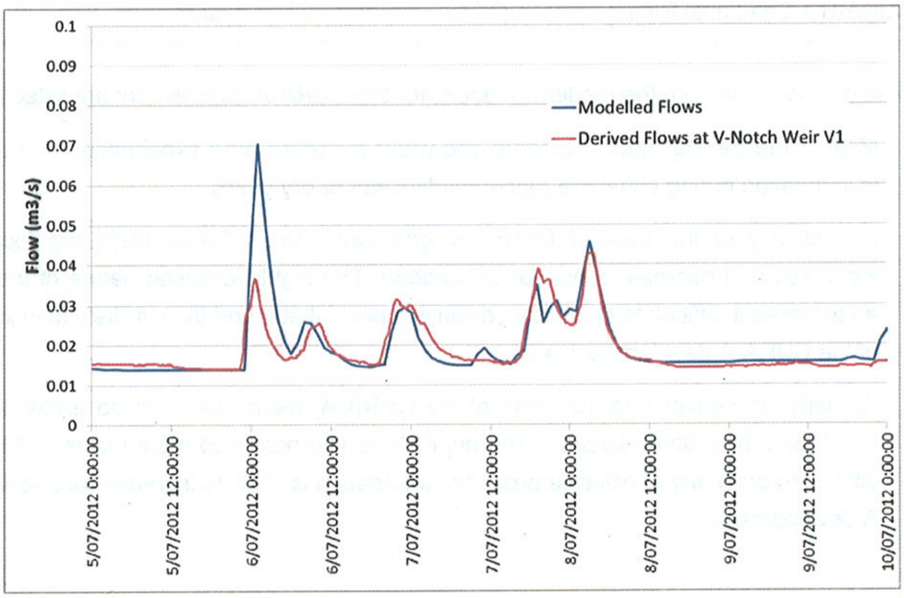


Figure 3-2 Zoom: Comparison of Low Flows – Modelled versus Derived at V1 Low Flow Weir

3.3 Model Results

The modelling results have been presented in terms of a percentage of time that a particular point is inundated. Impacts maps have been prepared for the 8 scenarios listed in Table 3-1. These are presented as **Error! Reference source not found.** to Figure 3-10.

Table 3-1 Summary of Impact Scenarios Assessed

Impact Scenario[1]	Wet or Dry Year?	Base Case Scenario[1]	Comparison Scenario[1]	Figure
Impact of CURA-A	Wet	Existing Case	CURA-A	**Error! eference source not found.**
Impact of CURA-A	Dry	Existing Case	CURA-A	Figure 3-3
Impact of CURA-B	Wet	Existing Case	CURA-B	Figure 3-4
Impact of CURA-B	Dry	Existing Case	CURA-B	Figure 3-5
Impact of CURA-A + CURA-B	Wet	Existing Case	CURA-A + CURA-B	Figure 3-6
Impact of CURA-A + CURA-B	Dry	Existing Case	CURA-A + CURA-B	Figure 3-7
Impact of CURA-A + CURA-B + Sea Level Rise	Wet	Existing Case	CURA-A + CURA-B + SLR	Figure 3-8
Impact of CURA-A + CURA-B + Sea Level Rise	Dry	Existing Case	CURA-A + CURA-B + SLR	Figure 3-9

Some observations from the modelling results for the CURA-A assessment are listed below:

- Most of the Ballina Nature Reserve and wider modelled area experiences less than 1% change in inundation during either the representative wet or dry years;
- Immediately to the east of Ballina Heights and the CURA-A, there are localised areas of increased and decreased inundation duration. The highly localised nature of the impacts in this area makes it difficult to draw any conclusive proof that inundation is likely to increase as a result of the CURA-A development; and
- Similarly, immediately to the north of the CURA-A, there are localised areas of increased and decreased inundation duration. The highly localised nature of the impacts in this area makes it difficult to draw any conclusive proof that inundation is likely to increase as a result of the CURA-A development.

[1] An "impact scenario" is formed by subtracting the "base case scenario" from the "comparison scenario". For example, the "impact of CURA-A" is formed by subtracting the "existing case scenario" time of inundations from the "CURA-A scenario" time of inundations.

Some observations from the modelling results for the CURA-B assessment are listed below:

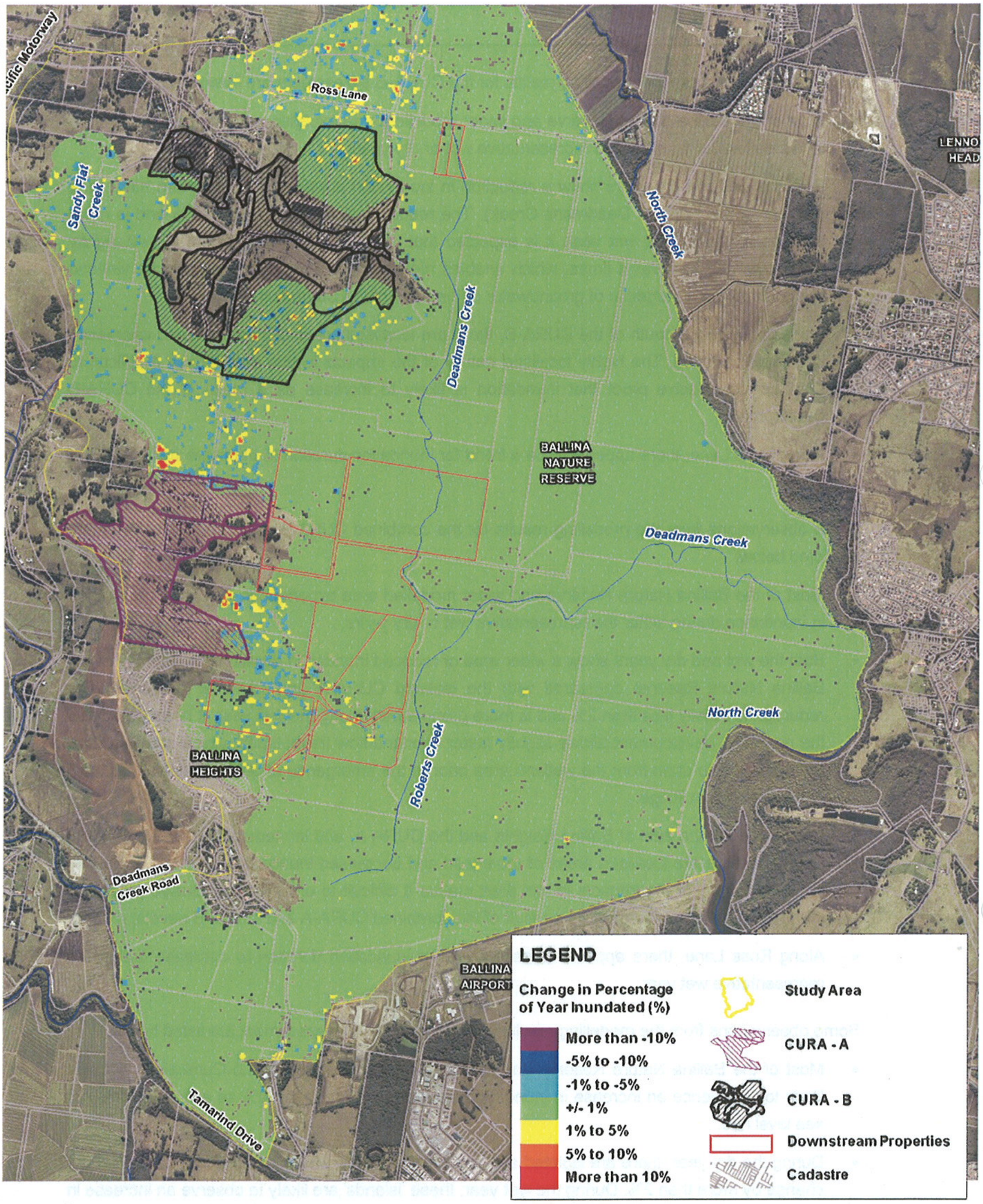
- Most of the Ballina Nature Reserve and wider modelled area experiences less than 1% change in inundation during either the representative wet or dry years.
- Both the wet and dry years show a reduction in inundation duration in the northern half of the study area (i.e. north of Deadmans Creek). The reduction is mostly less than 2% and is more pronounced during the wet year. It is expected that the proposed development allows slightly faster overland flow travel times, which enables more surface water to drain from the wetland area prior to the emergence of groundwater at the base of the Cumbalum Ridge.
- Immediately to the south of the CURA-B, there are localised areas of increased and decreased inundation duration. The highly localised nature of the impacts in this area makes it difficult to draw any conclusive proof that inundation is likely to increase as a result of the CURA-B development.
- Along Ross Lane, there appears to be a trend for inundation duration to decrease during the wet year.

Some observations from the modelling results for the combined CURA-A and CURA-B assessment are listed below:

- Most of the Ballina Nature Reserve and wider modelled area experiences less than 1% change in inundation during either the representative wet or dry years.
- Both the wet and dry years show a wider area of reduced inundation duration across most of the Ballina Nature Reserve compared with the isolated CURA-A and CURA-B scenarios. The reduction is mostly less than 2% and is more pronounced during the wet year. It is expected that the proposed development allows slightly faster overland flow travel times, which enables more surface water to drain from the wetland area prior to the emergence of groundwater at the base of the Cumbalum Ridge.
- Immediately to the east of Ballina Heights and the CURA-A, and immediately to the north of the CURA-A, there are localised areas of increased and decreased inundation duration. The highly localised nature of the impacts in this area makes it difficult to draw any conclusive proof that inundation is likely to increase as a result of the combined CURA-A and CURA-B developments.
- Along Ross Lane, there appears to be a trend for inundation duration to decrease during the representative wet year.

Some observations from the modelling results for the sea level rise assessment are listed below:

- Most of the Ballina Nature Reserve and modelled area to the east of the Cumbalum Ridge is likely to experience an increase in inundation duration by more than 10% as a result of 900mm sea level rise.
- During the dry year, there are isolated areas of higher ground where inundation duration will not change by more than 2%. During the wet year, these 'islands' are likely to observe an increase in inundation duration by up to 5%.
- Sandy Flat is likely to only experience significant change during wetter years.



Title:

Wet Year Impact of CURA A Development Change in Percentage of Year Inundated

Figure: 3-3

Rev: B

N

0 400 800m
Approx.Scale

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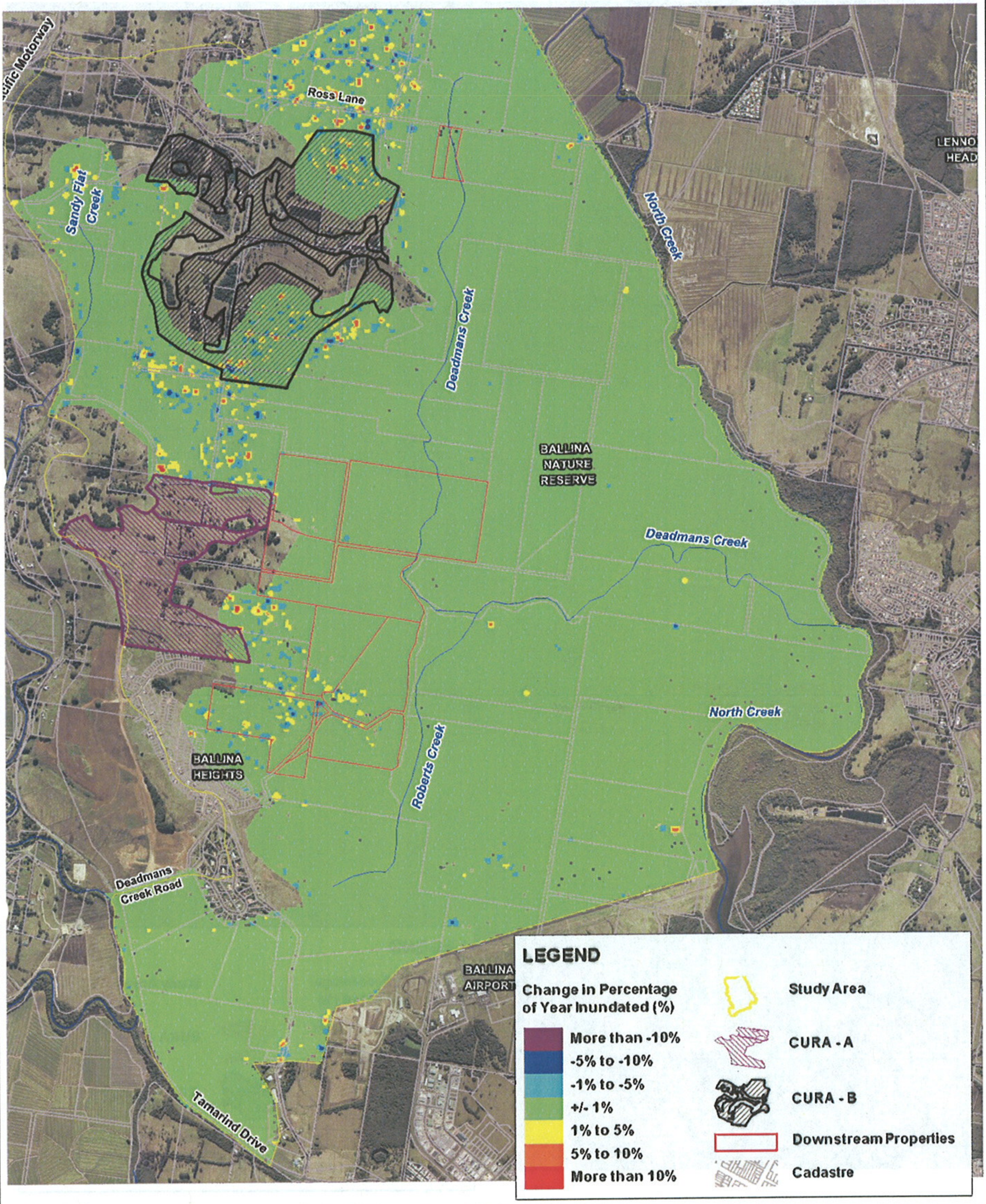
Filepath : I:\B19181_I_clb_Cumbalum\WOR\FLD_004_121205_Wet_Year_Impact_of_Cura_A.WOR



Title:

Dry Year Impact of CURA A Development
Change in Percentage of Year Inundated

Figure: 3-4

Rev: B

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N

0 400 800m
Approx.Scale

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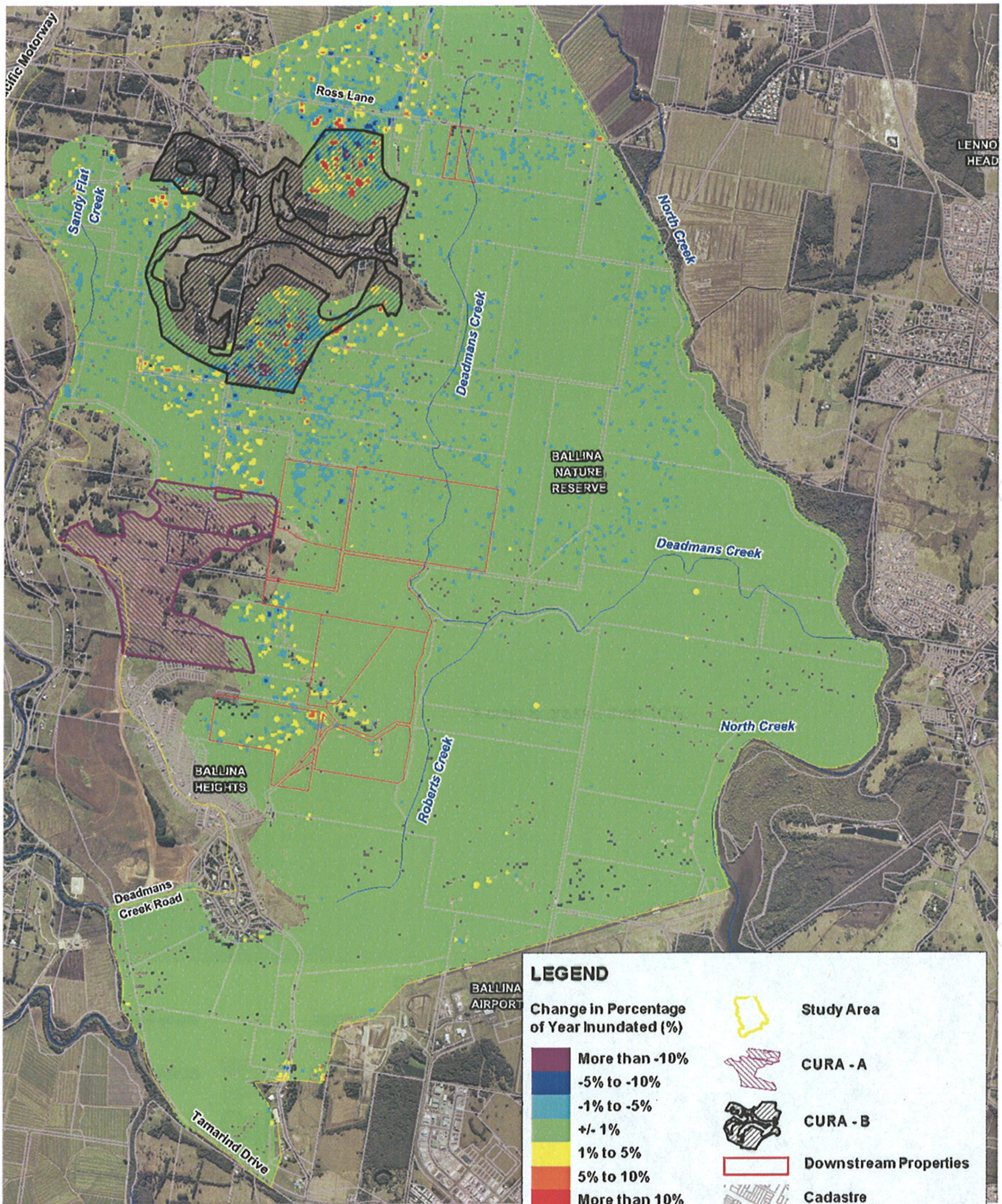

Title:

Wet Year Impact of CURA B Development Change in Percentage of Year Inundated

Figure: 3-5

Rev: B

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0 400 800m
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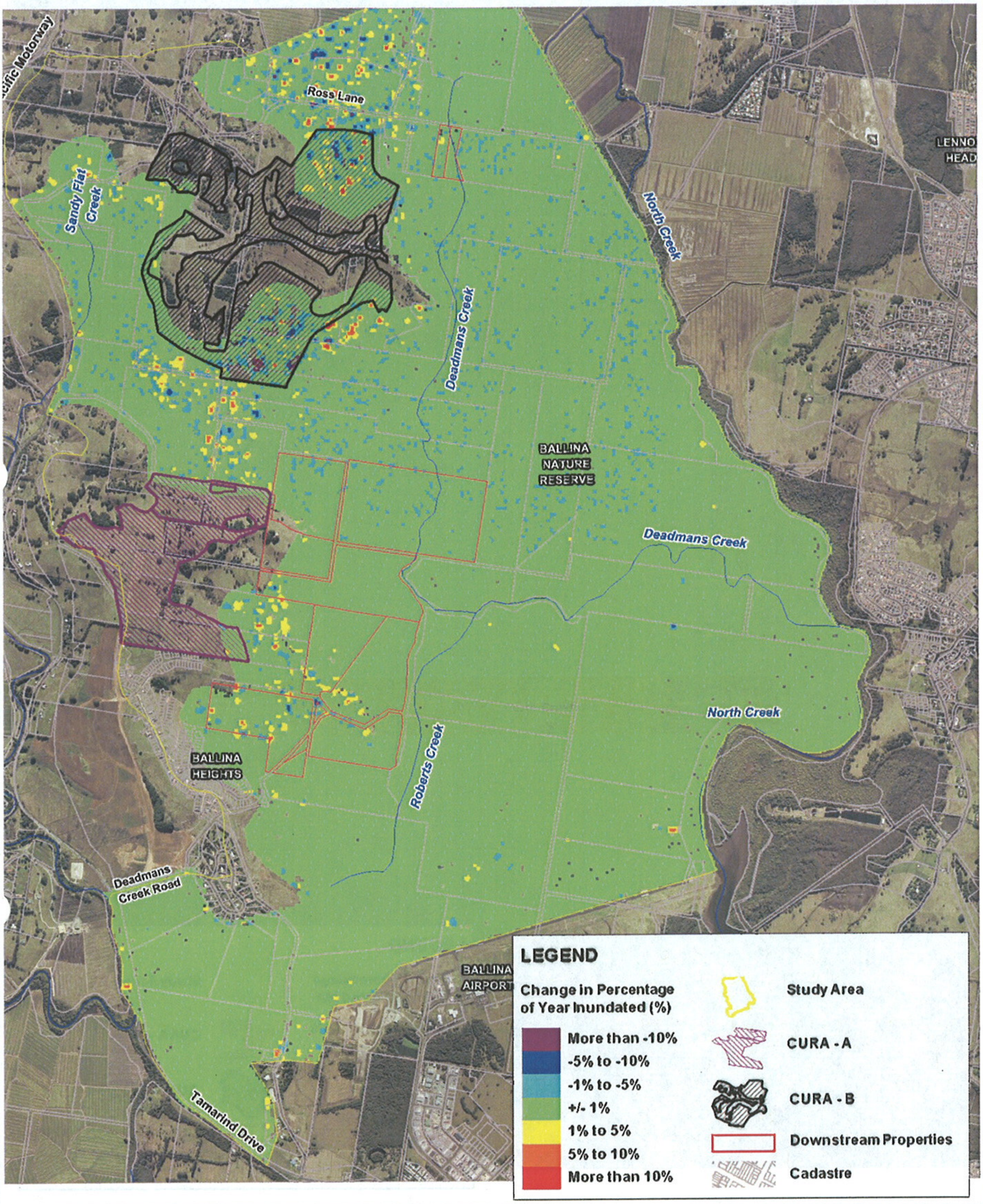

Title:

Dry Year Impact of CURA B Development
Change in Percentage of Year Inundated

Figure: 3-6

Rev: B

N

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Approx.Scale

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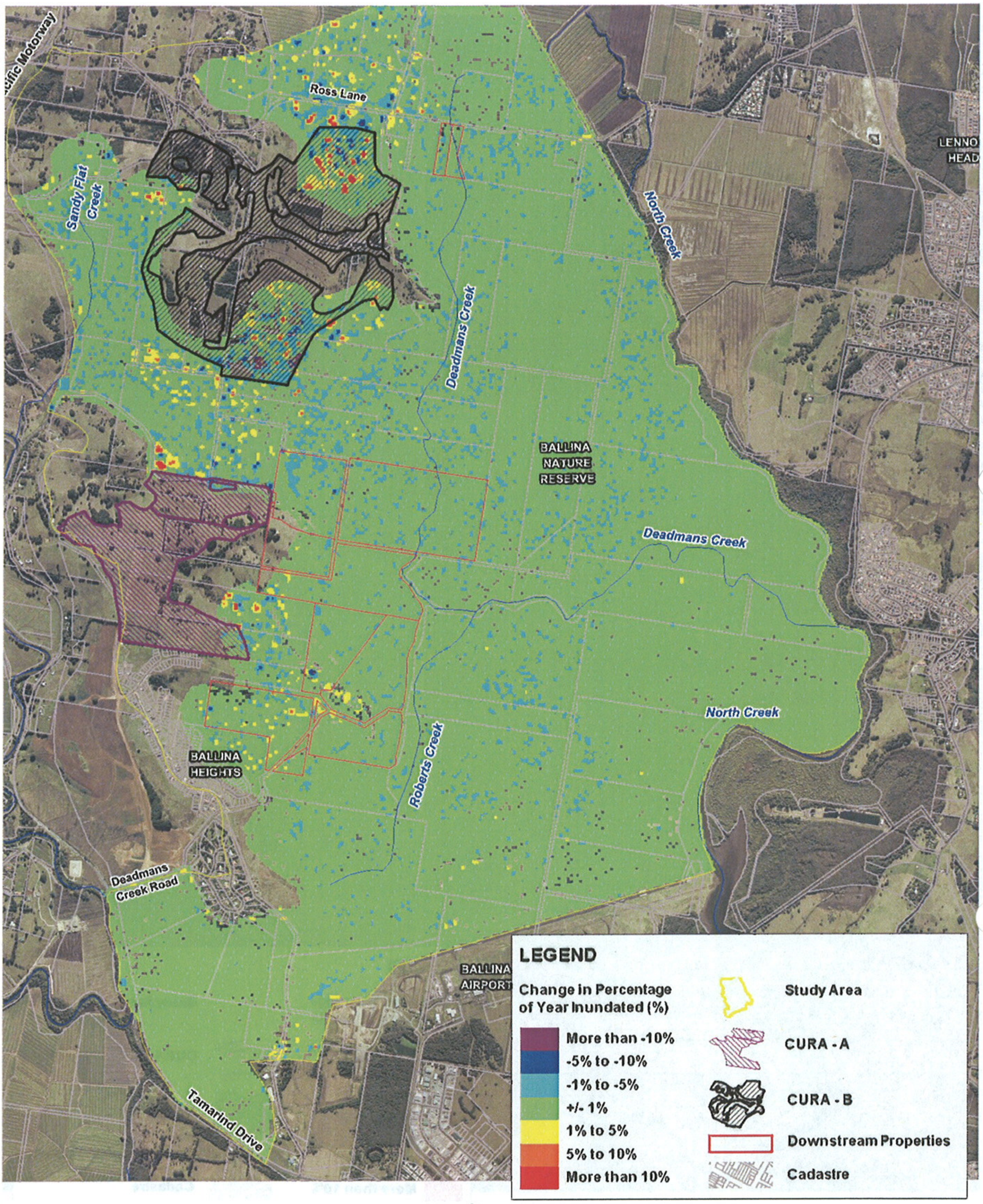
Filepath : I:\B19181_I_clb_Cumbalum\WOR\FLD_006_121205_Dry_Year_Impact_of_Cura_B.WOR



Title:

Wet Year Impact of CURA A & CURA B Developments Change in Percentage of Year Inundated

Figure: 3-7

Rev: B

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N

0 400 800m

Approx.Scale

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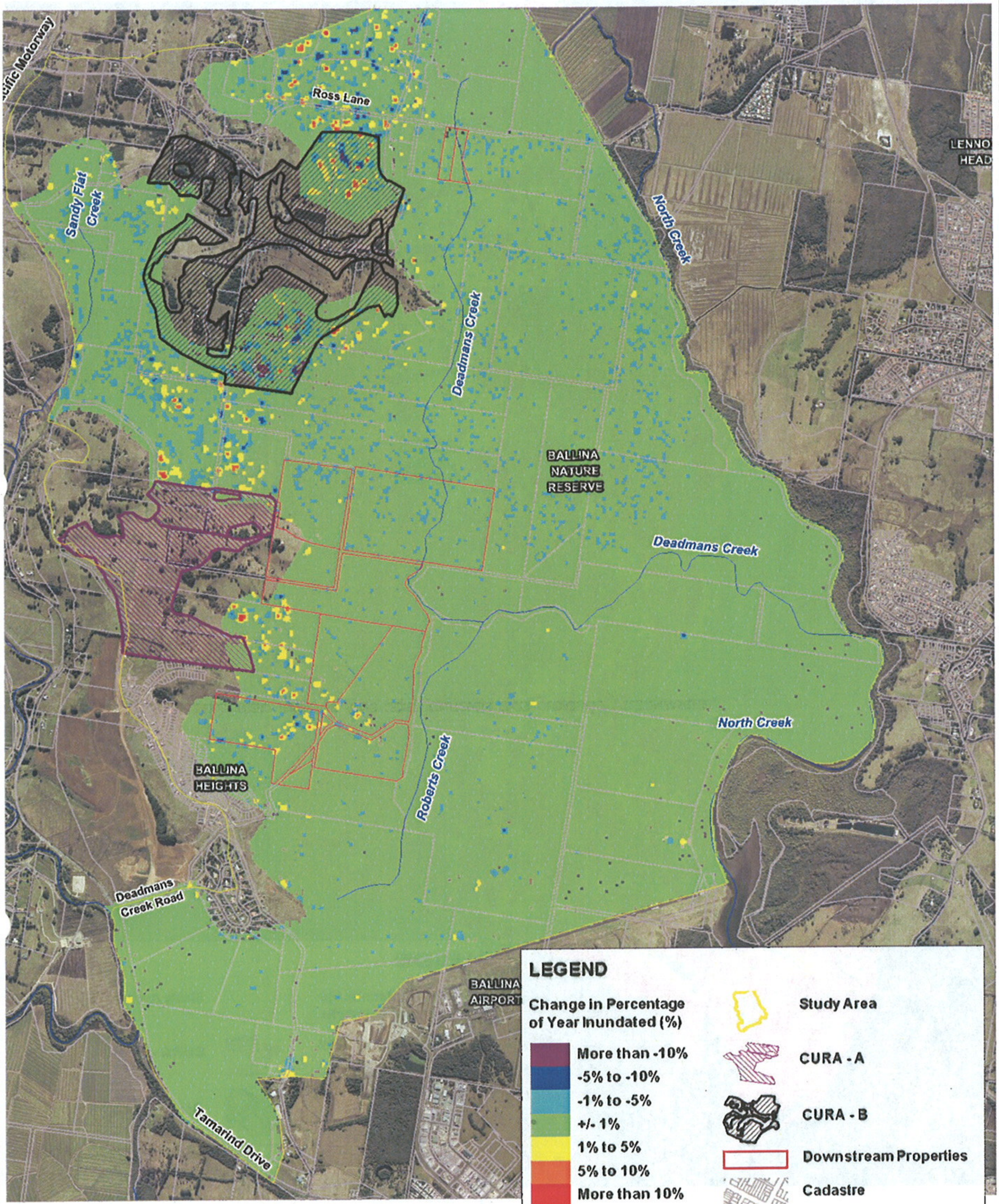
Filepath : I:\B19181_I_clb_Cumbalum\WOR\FLD_007_121205_Wet_Year_Impact_of_Cura_A+B.WOR



Title:

Dry Year Impact of CURA A & CURA B Developments Change in Percentage of Year Inundated

Figure: 3-8

Rev: A

N

0 400 800m
Approx.Scale

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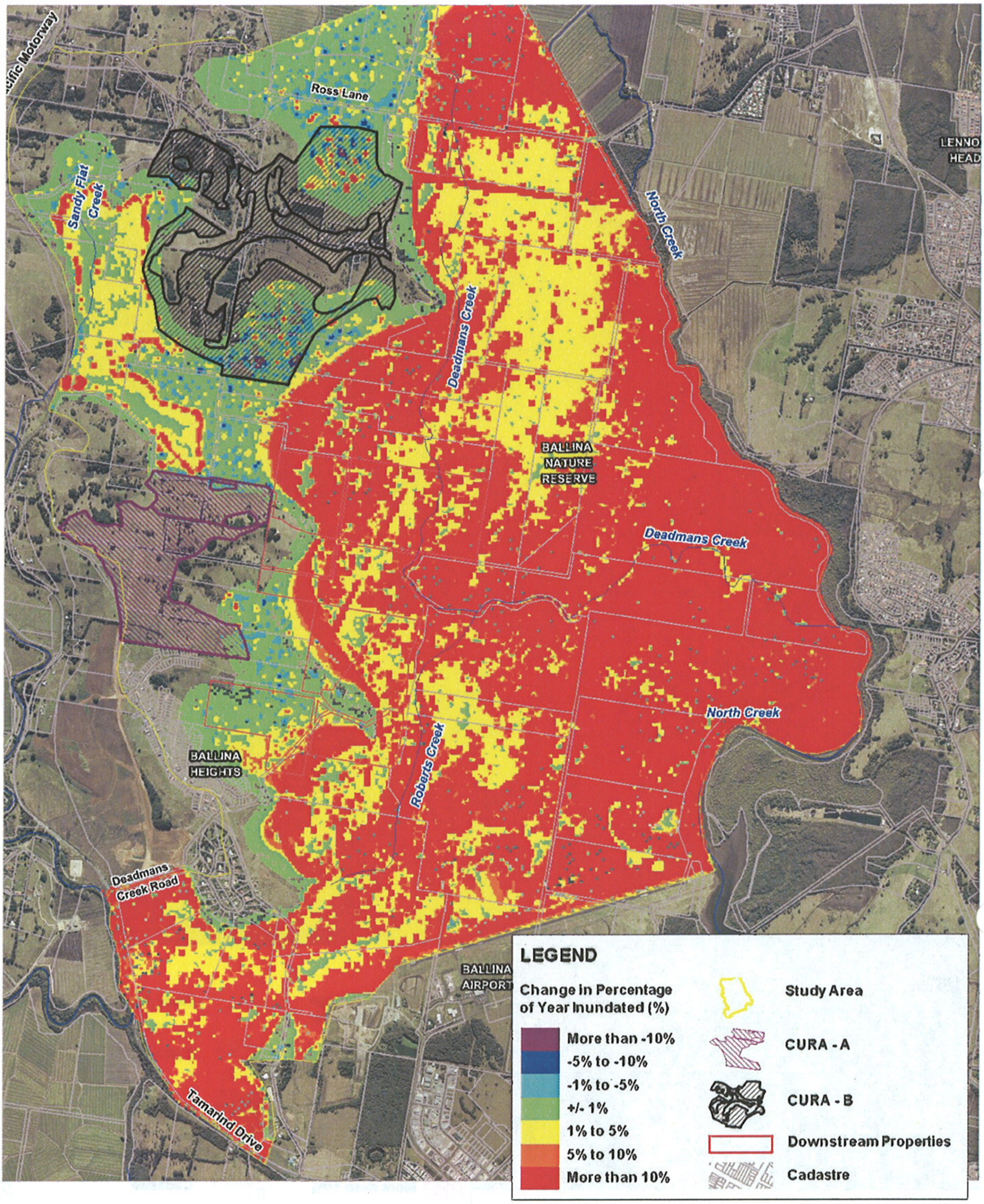
Filepath : I:\B19181_I_clb_Cumbalum\WOR\FLD_008_121205_Dry_Year_Impact_of_Cura_A+B.WOR



Title:
Wet Year Impact of CURA A & B Developments and Sea Level Rise Change in Percentage of Year Inundated

Figure: 3-9

Rev: B

N

0 400 800m
Approx.Scale

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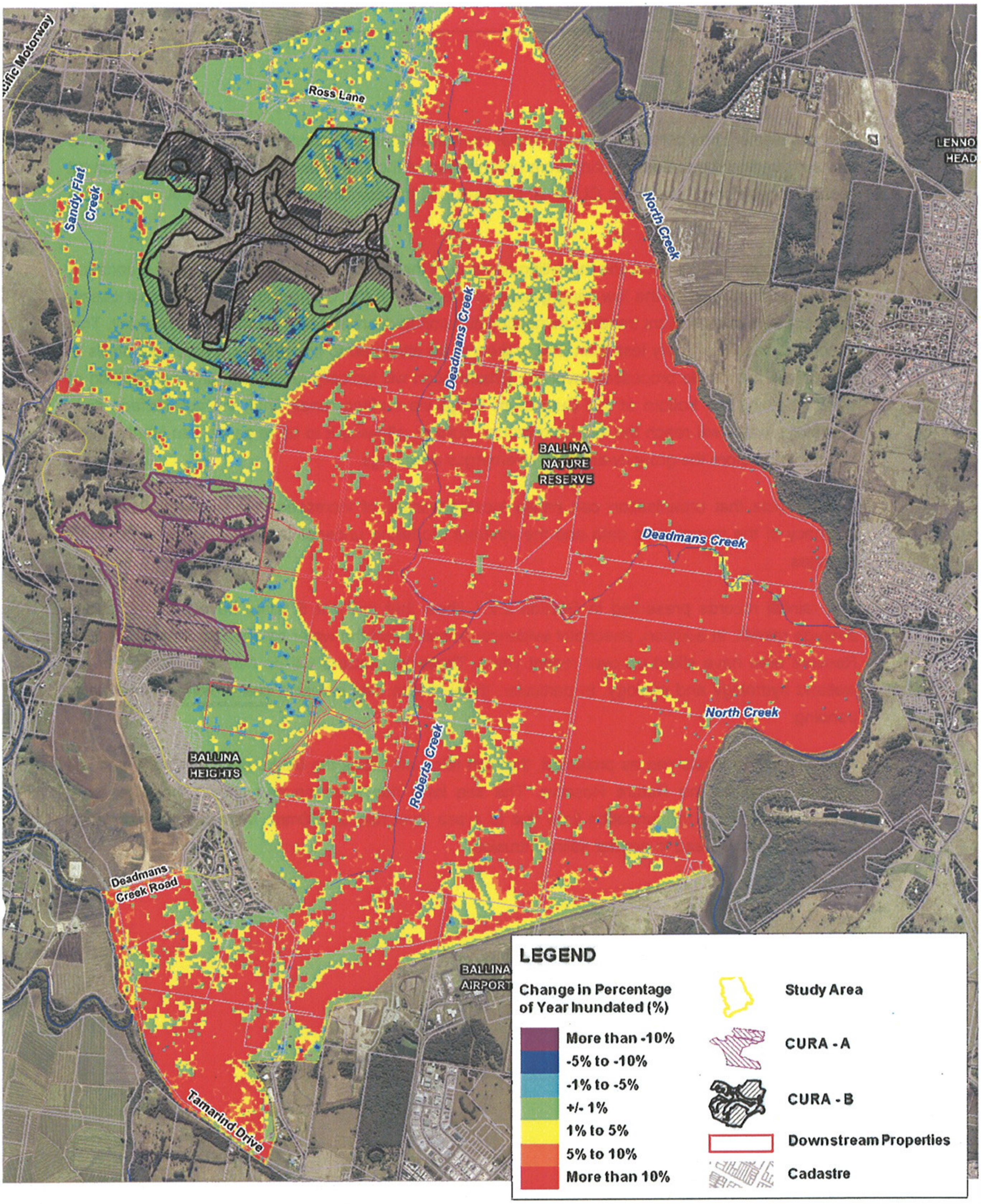
Filepath : I:\B19181_I_clb_Cumbalum\WOR\FLD_009_121205_Wet_CC_Year_Impact_of_Cura_A+B.WOR



Title:

Dry Year Impact of CURA A & B Developments and Sea Level Rise Change in Percentage of Year Inundated

Figure: 3-10

Rev: B

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0 400 800m
Approx.Scale

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Filepath : I:\B19181_I_clb_Cumbalum\WOR\FLD_010_121205_Dry_CC_Year_Impact_of_Cura_A+B.WOR

4 DISCUSSION

This assessment has considered the potential inundation impacts across the Ballina Nature Reserve and surrounding properties resulting from urbanisation of the Cumbalum Ridge. Three development scenarios have been assessed; CURA-A, CURA-B and the combined effect of CURA-A and CURA-B.

In all development scenarios, the modelling has shown there to be less than 1% change in inundation duration across most of the low lying ground at the base of the Cumbalum Ridge. In most cases, there appears to be a slight trend for inundation duration to decrease as a result of development. This minor decrease (generally less than 2%) is likely to be attributed to the change in response times of the various hydrologic processes involved. Urbanisation will typically result in a larger proportion of water reaching the bottom of the Cumbalum Ridge via surface runoff, than via sub-surface flow. Therefore, water will reach the low lying ground quicker, allowing it to be released into North Creek sooner, and before the groundwater flow re-emerges as springs.

It is possible that urbanisation can cause localised areas of increased inundation, however, the accuracy of the topographic data and the inherent modelling uncertainties have not detected such changes.

The rainfall records presented in Section 2.2.1 show that the last 5 years have been all above average rainfall. In addition, anecdotal evidence indicates that the water courses draining the Nature Reserve area have silted up over recent years. These two factors will be causing changes to the wetland hydrology and ecology. In particular, there is less tidal intrusion and prolonged freshwater ponding.

However, if sea levels rise as projected, the high tides will break the banks of North Creek and will start to penetrate the Nature Reserve. The sea level rise scenario has shown these to be a substantial increase to inundation time due to a sea level rise of 900mm. More regular inundation from high tides will lead to greater saline intrusion.

5 REFERENCES

APP (2012), "Progress Report on the Hydrological Impacts of the Proposed Development - CURA-A Precinct Rezoning", Submission by Ardill Payne & Partners to Ballina Shire Council for Vixsun Pty Ltd, Sheather, Barlow, Intrapac, February 2012.

BMT WBM (2010), "Draft NSW MUSIC Modelling Guidelines", BMT WBM on behalf of Sydney Metropolitan Catchment Management Authority, R.B17048.001.01, August 2010.

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