

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

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

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

The Greendale Creek Flood Study constitutes the first stage of the management process for the catchment. This study has been prepared by WMAwater for Northern Beaches Council and was undertaken to provide the basis for future management of flood liable lands within the study area.

EXECUTIVE SUMMARY

The Greendale Creek Flood Study catchment area is located within the Northern Beaches Council Local Government Area (LGA). The study area includes the suburbs of Beacon Hill, Brookvale, Curl Curl, Freshwater and North Curl Curl, comprising a total area of approximately 482 ha (0.48 km²). Curl Curl Lagoon is a significant feature of the lower catchment with Greendale Creek and the majority of the study area draining to it, while some of the eastern-most portion of the catchment to the north and south drains directly to the ocean. The surface area of Curl Curl Lagoon is approximately 5.7 ha (0.057 km²), making up approximately 12% of the catchment area. The urbanised part of the catchment consists of commercial and light industrial development in the lower areas, and residential development in the middle and upper catchment areas. “The Kilns” development is a notable feature of the upper catchment which is bounded to the north and west by steep, natural forested land with sharply incised streams.

The Greendale Creek catchment upstream of Warringah Road (A38) consists of a mix of residential development, sporting fields and natural forested land with drainage infrastructure passing under the road. The catchment downstream of The Kilns is primarily urban residential and industrial areas, with grassed sports fields downstream of Harbord Road (built over a former rubbish dump). The catchment consists of a mix of pervious and impervious surfaces with piped and overland flow drainage systems.

The work undertaken in this study includes:

- preparing suitable models of the catchment and floodplain for use in a subsequent Floodplain Risk Management Study;
- estimating flood behaviour in terms of design flood levels, depths, velocities, flows and flood extents within the study area;
- preparing maps of provisional hydraulic categories and provisional hazard categories;
- determining flood planning levels and the flood planning area;
- preparing information for emergency response planning; and
- assessing the sensitivity of flood behaviour to potential climate change effects such as increases in rainfall intensities and sea level rise.

COMMUNITY CONSULTATION

A questionnaire was distributed to residents in the study area in August 2019. The purpose of the questionnaire was to identify which residents had experienced problems with flooding and to collate historical flood data. A total of 113 responses relating to flooding within the Greendale Creek catchment were received from the distributed questionnaires, via both written and online submissions.

Of the responses received, 34 respondents had experienced flooding due to floodwater or stormwater, with 30 respondents indicating that their home was affected and 4 indicating that their business was affected. One respondent indicated that their main building was affected by above floor level flooding with the remainder indicating that flooding affected their garage, yard

or other parts of their property.

MODELLING SUMMARY

Estimation of flood behaviour in the catchment was undertaken as a two-stage process consisting of:

1. Hydrologic modelling to convert rainfall estimates to overland flow runoff;
2. Hydraulic modelling to estimate overland flow distributions, flood levels and velocities.

MODEL CALIBRATION

There is only limited data for model calibration. While there are good records of the water level within the lagoon, the records of overland flow and flooding throughout the catchment are sparse and generally qualitative descriptions, rather than recorded flood levels for specific events. The November 2018 event was chosen for model calibration and the modelled flood behaviour was compared to the gauged water level hydrograph at the Curl Curl gauge (213426), and qualitative descriptions of flooding, obtained from Council's customer complaints database, local flood investigations and community consultation responses.

The accuracy of the resulting design flood information is largely dependent upon the ability of the modelling system to accurately replicate historical flood data. As relatively few historical records are available for calibration the accuracy of the design flood levels is likely to be around +/- 0.3m to +/- 0.5m. This level of accuracy is typical of systems like Greendale Creek in the Sydney basin. The accuracy can be significantly improved upon if all flood related information (peak levels, velocity estimates, flood extents, photographs, videos etc) in future events is recorded and used for model calibration.

DESIGN FLOOD ESTIMATION

Design flood information was obtained by including design rainfalls from the Bureau of Meteorology into the hydrologic model and then inputting the flows into the hydraulic model. The critical storm duration (duration that produces the highest flood level) was determined based on the mean of 10 temporal patterns for each duration and varied across the catchment from 30 to 180 minutes, although the variation was relatively minor and the 45 minute design storm burst was found to adequately represent the typical behaviour. Design flood information is provided in Appendix D, E and F.

SENSITIVITY ANALYSIS

Sensitivity analysis was undertaken to test the impact of varying the following key parameters:

- catchment lag factor (C);
- rainfall losses;
- roughness;
- structure blockage;
- energy losses;
- initial water level; and

- increases to rainfall intensity and sea level resulting from climate change.

The input having the most widespread influence on flood levels was rainfall intensity.

INFORMATION TO SUPPORT PLANNING AND MANAGING FLOOD RISK

The following information in regard to the above has been provided:

- depth and velocity of floodwaters across roads;
- capacity of stormwater network (i.e. in what event will overland flow occur above a stormwater pipe);
- description of "hot spots";
- mapping of flood planning constraints categories; and
- mapping of the flood planning area.

A discussion of the AEP terminology and a glossary of other flood-related terms is provided in Section 14.

1. INTRODUCTION

1.1. Background

The Greendale Creek Flood Study covers the Greendale Creek catchment, including Curl Curl Lagoon, which is located in the northern coastal suburbs of Sydney. The study area includes the suburbs of Beacon Hill, Brookvale, Curl Curl, Freshwater and North Curl Curl. The catchment lies within the Local Government Area (LGA) of Northern Beaches Council.

This flood study provides information about existing flood risk in the catchment. Flood modelling tools were developed that can be used by Council for decision-making about land-use planning, and in future studies to assess the effectiveness of potential measures to reduce flood risk. The models were calibrated using observations from historical floods, and used to estimate the impacts of flooding for a range of standardised “design” flood probabilities. This modelling was completed in accordance with the guidelines in Australian Rainfall and Runoff (Reference 1).

Flooding in the catchment can occur when intense local rainfall generates runoff exceeding the capacity of drainage channels and creeks, or from flooding of Curl Curl Lagoon leading to inundation of low lying areas in the lower Greendale Creek catchment. Previous flood studies and floodplain risk management studies (References 2, 3 and 4) of Curl Curl Lagoon were undertaken in 2004 and 2005, respectively. However no detailed catchment study considering overland flooding of the Greendale Creek catchment upstream of the influence of lagoon flooding has previously been undertaken.

Northern Beaches Council is responsible for managing development in accordance with flood risk, as per the NSW Floodplain Development Manual (FDM, Reference 5). This study will provide Council with relevant flood information for strategic planning and development assessment.

1.2. Scope of Study

The Flood Study defines design flood behaviour for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% Annual Exceedance Probability (AEP) design storms and the Probable Maximum Flood (PMF) in the Greendale Creek catchment. This report documents the data, methodology and outputs from the flood modelling exercise, including the following specific tasks:

- the collection and collation of existing information relevant to the study which includes the data already held by Council as well as other information, such as rainfall data;
- the preparation of hydrologic and hydraulic models capable of defining the flood behaviour for the study area for a wide range of design flood probabilities;
- undertaking sensitivity analysis;
- assessing the impacts of projected future changes to rainfall intensity and sea level rise
- the interpretation and presentation of model results to describe and categorise flood behaviour and hazard for a range of design storm events for the existing catchment conditions;
- determining the Preliminary Flood Planning Area extent.

2. BACKGROUND

2.1. Study Area

The study area covers approximately 470 hectares (4.7 km²), comprising the Greendale Creek catchment, including Curl Curl Lagoon. The Greendale Creek catchment is situated within the northern beaches of Sydney and includes parts of the suburbs of Beacon Hill, Brookvale, Curl Curl, Freshwater and North Curl Curl. The catchment (Figure 1) drains into Curl Curl Lagoon which is an intermittently closed and open lagoon (termed an ICOLL) of approximately 5.7 ha (0.057 km²) (Reference 2).

The catchment generally flows from west to east, with the upper Greendale Creek catchment flowing in a south-easterly direction through residential and industrial areas. The trunk drainage system exits at Harbord Road into the modified semi-natural channel of Greendale Creek which discharges into Curl Curl Lagoon. Elevations in the upper part of the catchment to the north-west reach approximately 150 mAHD (mapping of the topography from LiDAR aerial survey is shown in Figure 2). The topography within the study area ranges from moderately steep terrain, in the upper catchment where grades of approximately 9% in the suburban areas are common to gently sloping, particularly in the industrial areas upstream of Harbord Road.

The land use within the catchment consists primarily of medium and high density urban residential development with a considerable amount of industrial development in the suburb of Brookvale, together with parks and sporting ovals, adjacent to Curl Curl Lagoon. The steep forested area in around “The Kilns” is a notable feature of the upper catchment. Brookvale Oval is situated adjacent to Pittwater Road and the earthen bund to the north and east of the field is a notable topographic feature, which affects overland flow behaviour in the local area. A large industrial area characterises the lower Greendale Creek catchment which is bounded by Harbord Road to the east, Pittwater Road to the north and west and Wattle Road to the south.

The catchment includes natural creek channels, kerbs and gutters, pits and pipes, and a network of trunk drainage elements including culverts and concrete-lined or otherwise modified open channels. These trunk drainage assets are primarily owned by Northern Beaches Council.

2.2. Curl Curl Lagoon

Curl Curl Lagoon is classified as an ICOLL, as the ocean entrance can be either open or closed. The Curl Curl Lagoon entrance condition has a significant influence on water levels up to the vicinity of Harbord Road (Reference 3), where there is a gross pollutant trap. The berm height at the entrance of Curl Curl Lagoon varies significantly over time.

Management of the Curl Curl Lagoon entrance is the responsibility of Northern Beaches Council, and involves mechanical opening of the entrance berm when the lagoon gauge reaches a specified level (2.2 mAHD at the time of writing), allowing breakout to occur and for the lagoon to discharge into the ocean. This trigger level for mechanical opening is based on consideration of inundation of roadways in the vicinity of low lying properties in Surf Road, with the minimum

level of Surf Road at approximately 2.3 mAHD.

The lagoon often breaks out naturally before the lagoon reaches this height, as the lagoon volume is relatively small compared with the catchment size, and the runoff that is generated is often sufficient to cause a breakout at the entrance before the berm reaches the level requiring intervention. If the berm has built up higher than the trigger level and enough rainfall is forecast for possible flooding, Council lowers the berm to allow a natural breakout just below the trigger level. Unauthorised breakouts have also been known to occur.

2.3. Historical Flooding

Flooding in the Greendale Creek catchment can occur when intense local rainfall generates runoff exceeding the capacity of drainage channels and creeks, producing overbank flow or overland flooding. The lower catchment is also subject to mainstream flooding from Curl Curl Lagoon. Flooding in some areas may be exacerbated by the blockage of hydraulic structures and the presence of obstructions to overland flow paths such as buildings.

The April 1998 flood event was selected for model calibration in the 2005 Dee Why Lagoon and Curl Curl Lagoon Flood Study (Reference 2) due to the availability of anecdotal evidence describing flooding in the Greendale Creek catchment. This peak burst rainfall intensity for this event approximates a 10% AEP event (Reference 2).

A more recent notable flood event occurred in November 2018, which caused flooding in the catchment and a breakout of Curl Curl Lagoon.

Some properties located below the berm height of Curl Curl Lagoon, such as those located at the southern end of Surf Road, can be inundated due to elevated lagoon levels.

2.4. Previous Studies

Previous flood investigations have been completed for the Greendale Creek catchment. A brief summary of previous studies relevant to the current investigation are provided below.

2.4.1. Dee Why Lagoon and Curl Curl Lagoon Flood Studies

This study was undertaken by Lyall and Associates (Reference 2) in 2004 to determine flood behaviour for Dee Why Lagoon and Curl Curl Lagoon. The area under investigation included the floodplains of Greendale Creek and Curl Curl Lagoon catchment to Harbord Road and parts of the industrial areas to the intersection of Winbourne Road and Mitchell Road. Flood behaviour upstream of the Winbourne Road culvert was not included in the hydraulic model.

The study used a RORB hydrologic model to estimate runoff hydrographs and a 1D MIKE-11 hydraulic model to define flood behaviour, except for the "Brookvale Industrial Estate Area" between Winbourne Road and Harbord Road, Where a series of HEC-RAS models were established to represent flooding along the road network. A limited calibration of the Mike-11 hydraulic model was undertaken using the available historical data for the April 1998 event. The

HEC-RAS modelling of the Brookvale industrial estate was not calibrated or verified – it was a relatively crude modelling approach that used a separate HEC-RAS model for each street with inflows determined from the hydrologic model.

Rainfall data from AR&R 1987 (Reference 6) was applied to produce design flood levels for the 20%, 10%, 2% and 1% AEP design events.

The study did not define the extent of inundation upstream of Harbord Road due to the limitations in the HEC-RAS modelling approach discussed above. It was noted that future flood studies should extend the hydraulic model westward of Harbord Road to provide a more detailed understanding of flood levels in this area.

2.4.2. Dee Why Lagoon and Curl Curl Lagoon Floodplain Risk Management Study & Plan

This 2005 study by Lyall and Associates (References 3 and 4) was prepared to assist the former Warringah Council in the development of a Floodplain Risk Management Study and Plan using the results drawn from the Flood Study (Reference 2). This was undertaken by identifying the nature and extent of the flood hazard and the flood damage costs for commercial/industrial and residential developments.