SUTHERLAND SHIRE COUNCIL

# KURNELL FLOODPLAIN RISK MANAGEMENT STUDY

## FINAL REPORT

JULY 2013

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# KURNELL TOWNSHIP FLOODPLAIN RISK MANAGEMENT STUDY

## FINAL REPORT
**JULY, 2013**

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| **Project**<br>Kurnell Township Floodplain Risk Management Study | **Project Number**<br>26086 |
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# KURNELL TOWNSHIP FLOODPLAIN RISK MANAGEMENT STUDY

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# FOREWORD

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

Under the Policy, the management of flood liable land remains the responsibility of local government. The State 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 Kurnell Township Floodplain Risk Management Study constitutes the second stage of the risk management process for the catchment area. It has been developed for Sutherland Shire Council's Floodplain Risk Management Committee by WMAwater (formerly Webb, McKeown & Associates) for the future management of flood liable lands in the Kurnell township catchment. Funding for this study was provided by Sutherland Shire Council and the Department of Environment and Climate Change and Water.

# EXECUTIVE SUMMARY

## KURNELL TOWNSHIP CATCHMENT

The Kurnell township catchment has an area of approximately 6.5 square kilometres and lies entirely within the boundaries of Sutherland Shire Council. It drains into Botany Bay (to the north) and Quibray Bay north of Sir Joseph Banks Drive (to the west). The catchment is bounded by Botany Bay National Park to the south and east. The lower reaches of the catchment are low lying with ill defined drainage paths. The catchment area is made up of approximately 25% national park, 15% residential, 20% wetland, and 40% industrial. The town's low lying nature and proximity to the Bay also makes it susceptible to flooding from tidal inundation.

## FLOOD STUDY

The Kurnell township flood study was initiated as a result of an *Initial Subjective Assessment of Major Flooding* report prepared for Sutherland Shire Council (Council) in 2004 (Reference 2), where the Kurnell township subcatchment was given a very high priority within the Council area in terms of the extent and frequency of flooding. The Kurnell Township Flood Study (Reference 2) was prepared by WMAwater in 2009 for Sutherland Shire Council.

**Outcomes:** The main outcomes of the Flood Study were as follows:

- full documentation of the methodology and results,
- preparation of flood level and hazard maps for the Kurnell township,
- an assessment of the potential impacts of climate change on flooding, and
- a modelling platform to form the basis for the Floodplain Risk Management Study.

## EXISTING FLOOD PROBLEM

A flood damages assessment for existing development in the Kurnell township was undertaken across a range of design events. This assessment was based on a detailed survey of building floor levels. Table i) indicates the estimated number of building floors which are likely to be flooded for a range of event magnitudes and the corresponding tangible damages. No consideration has been given for damages to public structures or utilities (bridges, roads, pumping stations) or for the complete collapse of structures due to flooding.

Table i) Summary of flood damages

| Event | Number of Buildings Inundated above Floor Level | | Total Tangible Flood Damages ($)* |
|---|---|---|---|
| | Residential | Non-Residential | |
| 20% AEP | 40 | 12 | $1,187,234 |
| 5% AEP | 59 | 15 | $1,795,721 |
| 1% AEP | 83 | 17 | $2,505,362 |
| PMF | 459 | 73 | $20,043,314 |
| | | AAD* | **$523,758** |

*Average Annual Damages

## FUTURE DEVELOPMENT

Based on recommendations from the *Kurnell Peninsula Land Use Safety Study*, it would appear that extensive new development in Kurnell is unlikely in the near future (Reference 3). However, Sutherland Shire Council note in the Project Brief for this study that there is still potential for redevelopment of Kurnell township.

## FLOODPLAIN RISK MANAGEMENT STUDY

The specific aims of this study are to:

- identify development and planning controls to regulate redevelopment in the flood affected properties and to ensure that future re-development does not significantly add to the overall potential damage,
- make recommendations for clauses in Council's Section 149 Certificate,
- make recommendations to adopt Flood Planning Levels (FPL) appropriate for the catchment,
- investigate available floodplain risk management measures along with prioritisation, staging of works and preliminary costings.

The subsequent Floodplain Risk Management Plan will document the recommended strategies.

## FLOODPLAIN RISK MANAGEMENT MEASURES

A list of all possible floodplain risk management measures which could be applied in the study area were initially developed for consideration. The assessment extended to examination of potential future development and its possible adverse impacts on flows and water quality. The measures were then assessed in terms of their suitability and effectiveness for reducing social, ecological, environmental, cultural and economic impacts. As part of this process a number of measures were identified as not being worthy of further consideration. A summary of the various floodplain management measures considered during the course of the study is presented in Table ii) together with a brief assessment of their viability for implementation as part of the Floodplain Risk Management Plan for the Kurnell township catchment.

## DEVELOPMENT MEASURES

Development measures relate to the management of future development from a flooding and water quality perspective. A summary of these measures is provided in Table iii).

Table ii) Review of Floodplain Management Measures

| MEASURE | RELEVANT SECTION | PURPOSE | COMMENT | ECONOMIC ASSESSMENT | IMPLEMENTATION VIABILITY |
|---|---|---|---|---|---|
| **FLOOD MODIFICATION:** | | | | | |
| DAMS AND RETARDING BASINS | Section 4.2.1 | Reduce flows from upper catchment areas. | The use of dams and retarding basins would not be practical as flooding is caused by overland flow and ocean inundation rather than mainstream flooding. No appropriate sites. | Not undertaken. | Not applicable. |
| CHANNEL MODIFICATIONS | Section 4.2.3 | Increase waterway conveyance to reduce flood levels. | Many issues (cost, environmental, social) and limited effectiveness on a lined channel system. The removal of major hydraulic restrictions (small culverts) will provide a hydraulic benefit but are cost prohibitive. A maintenance scheme to reduce the likelihood of blockage will be beneficial. | Preventative maintenance is cost effective. | Most measures not viable except preventative maintenance. Development of a Wetland Management Plan would assist in this regard. |
| LEVEES, FLOOD GATES AND PUMPS | Section 4.2.4 | Prevents or reduces the frequency of inundation of protected areas, assists in reducing problems with local runoff issues. | Levees could be built along Quibray Bay and Marton Park wetland. The effects of climate change should be considered in decision making. | Not undertaken. | Not applicable. |
| LOCAL DRAINAGE | Section 4.2.5 | To identify and reduce local drainage problems. | While land in Kurnell is generally flat, local filling and features result in ponding and/or diversion of runoff into footpaths and across private properties. Significant damage to yards and possibly buildings may occur as well as inconvenience to residents. Maintenance of a database would enable Council to identify issues and to determine an approach to resolve them. | Low cost. | Recommended that a database of flooding/ drainage issues be maintained. |
| STORM SURGE, WAVE RUNUP | Section 4.2.6 | To identify the effects of wave runup at Kurnell. | While the majority of Kurnell fronts Quibray Bay and has low exposure to storm surge, a separate study is recommended. | Not undertaken. | Not applicable. |
| **RESPONSE MODIFICATION:** | | | | | |
| FLOOD WARNING | Section 4.3.1 | Enable people to evacuate and take measures to reduce flood damages. | A specific flood warning system for Kurnell is not possible | Not applicable. | Not viable. |
| EVACUATION PLANNING | Section 4.3.2 | To ensure that evacuation can be undertaken in a safe and efficient manner or if | The SES should prepare a Local Flood Plan. | Relatively low cost. | Recommended. |

| MEASURE | RELEVANT SECTION | PURPOSE | COMMENT | ECONOMIC ASSESSMENT | IMPLEMENTATION VIABILITY |
|---|---|---|---|---|---|
| | | people don't evacuate that they take shelter somewhere safe. | | | |
| PUBLIC INFORMATION AND RAISING FLOOD AWARENESS | Section 4.3.3 | Educate people to minimise flood damages and reduce the flood risk. | A cheap and effective method but requires continued effort. Examples of methods are provided. | Benefits likely to be significant for relatively low cost. Effectiveness reduces with time since last flooding event. | Recommended. |
| **PROPERTY MODIFICATION MEASURES:** | | | | | |
| FLOOD PLANNING LEVELS | Section 4.4.1 | To minimise flood damages to new developments. | Council has established appropriate controls. However possible upgrades have been suggested. | Negligible cost. | Upgrades to be considered. |
| DEVELOPMENT CONTROL PLANNING | Section 4.4.2 | To ensure new development reduces the flooding and drainage impacts on downstream properties. | Council has established appropriate guidelines. However possible upgrades have been suggested. All Development Applications in the flood extent must be supported by a Flood Study. Identified flow paths to be maintained. | Negligible cost. | Upgrades to be considered. |
| HOUSE RAISING | Section 4.4.3 | Prevent flooding of existing buildings by raising habitable floor levels. | Potential to be applied to some houses, however further investigations are required. | High cost per property. | Further investigations are recommended. |
| VOLUNTARY HOUSE PURCHASE | Section 4.4.4 | To remove flood liable houses from the floodplain. | No applicable houses (very low hazard). Only to be considered if restoring flow paths. | Nil. | Do nothing. |
| FLOOD PROOFING | Section 4.4.5 | Prevents inundation of floodwaters. | Generally only suitable for non-residential buildings. | Depends upon building. Not funded by the State Government. | To be promoted where applicable. |

Table iii) Review of Development Measures

| MEASURE | REFER SECTION | PURPOSE | COMMENT | ECONOMIC ASSESSMENT | IMPLEMENTATION VIABILITY |
|---|---|---|---|---|---|
| CLIMATE CHANGE | Section 5.1 | Assess possible impacts of climate change and include in Flood Planning Level | The effect of sea level rise will affect design flood levels in the Kurnell catchment. An increase in rainfall intensity will affect the entire catchment. | Unknown. | Council should investigate a policy for Kurnell and this could be expanded to include all catchments in the local government area. |
| DEVELOPMENT INTENSIFICATION | Section 5.2 | Ensure no adverse impacts on flooding or water quality. | Council has a satisfactory water quality policy. Suggested upgrades to the policy on flooding have been provided. | Negligible. | To be considered. |
| **WATER SENSITIVE URBAN DESIGN:** | | | | | |
| REDUCE THE POTABLE WATER DEMAND | Section 5.3.2 | To minimise runoff volume and rate of runoff. | Should be employed where opportunities arise. | Variable. | To be promoted. |
| TREAT URBAN STORMWATER | Section 5.3. 4 | To improve runoff quality. | Should be employed where opportunities arise. | Variable. | To be promoted. |

# 1. INTRODUCTION

The Kurnell township catchment has an area of approximately 6.5 square kilometres. The catchment area is predominately occupied by national park and urban development (both residential and industrial).

## 1.1. Floodplain Risk Management Process

As described in the *Floodplain Development Manual* (Reference 1), the Floodplain Risk Management Process entails four sequential stages:

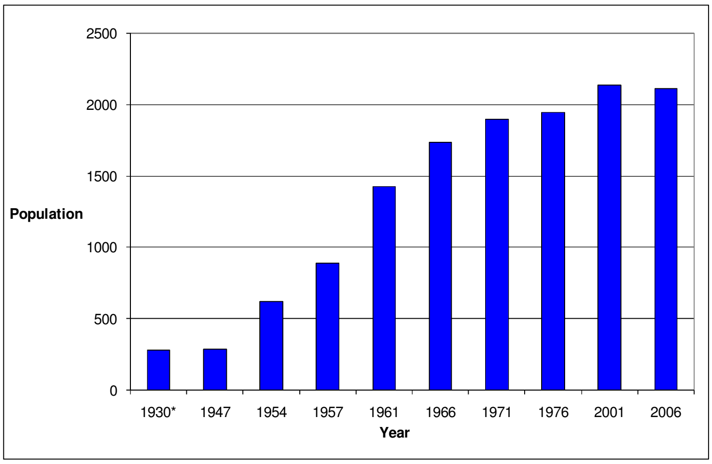
- Stage 1: Flood Study.
- Stage 2: Floodplain Risk Management Study.
- Stage 3: Floodplain Risk Management Plan.
- Stage 4: Implementation of the Plan.

The Kurnell Township Floodplain Risk Management Study constitutes the second stage in the process. The Kurnell Township Flood Study was completed in 2009 (Reference 2). A combination of hydrologic and hydraulic models was used in the Flood Study to determine design flood levels and extents for the Kurnell township catchment. The impacts of both catchment flooding and ocean flooding were considered.

## 1.2. History of Development

Kurnell is the site of Captain James Cook's first landing along the east coast of Australia in 1770. However, it was not until 1815 that the first land holding was taken. Minimal development occurred during the 1800's, with the majority of land owned by only a few individuals. There was no direct access to Kurnell in the 1800's and early 1900's other than by a small track, which limited development of the area. The introduction of a ferry service from Kurnell to San Souci in 1903 and to La Perouse in 1912 encouraged some expansion of the village. During the 1930's and 40's, Kurnell became a small fishing village with a population of less than 300 residents. It was not until the construction of the oil refinery and access road in the 1950's that Kurnell's development greatly advanced. By 1961, the population had reached 1424 (Reference 3).

Despite rapid growth following construction of the Caltex Oil Refinery, there has only been relatively minor development since the late 1980's. This would appear to be at least partly due to a risk assessment for Kurnell Peninsula (*Kurnell Peninsula Land Use Safety Study*), which was initially conducted in 1986, and was last updated in 2007 (Reference 4). The assessment found that the likelihood of catastrophic failure of the oil refinery and other industries was minimal. However, the impacts were considered potentially severe should failure occur. This in combination with the provision of only a single evacuation route via Captain Cook Drive resulted in residential development restrictions being imposed through regional planning controls. Consequently, the population had stabilised to just over 2000 residents by the 2001 Census (Reference 5). This can be seen from Diagram 1, which depicts the change in population since 1930.




*Approximate population estimate

**Diagram 1: Kurnell population growth between 1930 and 2001 (Source: References 3 and 5)**

Based on recommendations from the Land Use Safety Study, it would appear that extensive new development in Kurnell is unlikely in the near future (Reference 4). However, Sutherland Shire Council note in the Project Brief for this study that there is still potential for redevelopment of Kurnell township.

Land use and development is controlled under the Sydney Regional Environmental Plan No. 17 – Kurnell Peninsula. The current LEP zonings for the catchment are provided on Figure 2.

# 2. STUDY AREA

## 2.1. Catchment Description

The study area consists of the Kurnell township (Figure 1). Its catchment area extends further east and south of the township, and is bounded by Botany Bay to the north, Quibray Bay to the west, and Botany Bay National Park to the east and south.

The extent of the catchment area has been defined in consultation with Council, and covers the area draining to Quibray Bay north of Sir Joseph Banks Drive. This includes the entire township of Kurnell, as well as the Caltex Oil Refinery and part of the Botany Bay National Park.

The catchment encompasses an area of approximately 6.5km$^2$, of which approximately 25% is national park, 15% is residential, 20% is swamp or wetland, and 40% is industrial. The upper reaches of the catchment are predominantly steep, particularly within Botany Bay National Park where slopes of up to 25% can be found. However, the lower reaches of the catchment, including the Kurnell township itself, is typically flat and low lying. Elevations are generally below 3 m Australian Height Datum (AHD) with the exception of the north east corner, which reaches approximately 19.5 mAHD.

## 2.2. Preliminary Environmental Assessment

### 2.2.1. Water Quality

Recently an assessment (Reference 6) was made on Marton Park Wetland within the Kurnell Township catchment. A large portion of the catchment drains to this point, therefore the results can be said to be representative of the wider catchment.

### 2.2.2. Flora and Fauna

A large portion of the catchment is National park or wetland.

Marton Park wetland is an example of a Sydney Freshwater Wetland, an endangered ecological community (EEC) listed on the NSW Threatened Species Conservation (TSC) Act 1995 and known habitat for the Green and Golden Bell Frog (GGBF) which is listed as endangered in NSW and vulnerable at the national level. Marton Park Wetland also contains Swamp Oak Floodplain Forest, another EEC listed on the NSW TSC Act. The wetland also provides important habitat for a variety of native species and migratory birds.

### 2.2.3. Visual and Recreational Amenity

The *Marton Park Wetland Plan of Management* has revealed the value of the wetland to the community in terms of specific environmental and social values is extremely high due to the wetland providing green bushland areas and biodiversity. The existing wetland walk is the result of a community project, it is well utilised and has made the wetland a feature of recreation in Kurnell.

## 2.3. Previous Studies

A review of all known previous flooding and drainage investigations studies was undertaken as part of the Flood Study (Reference 2). A review of studies relating to the environmental, water quality and cultural was conducted as part of the Marton Park Wetland (Reference 6).

# 3. EXISTING FLOOD ENVIRONMENT

## 3.1. Flooding Mechanism

Flooding within the Kurnell catchment may occur as a result of a combination of factors including:

- An elevated water level in Botany and Quibray Bays (high tide and/or storm surge).
- Elevated water levels within the open channel which runs beside Captain Cook Drive and along roads and through private property as a result of intense rain over the Kurnell catchment. The water level in the channel and elsewhere may also be affected by constrictions (e.g. culverts, blockages, fences, buildings).
- Local runoff over a small area accumulating (ponding) in low spots. The relatively flat topography with limited potential for drainage lends itself to this form of flooding. This type of flooding may be exacerbated by inadequate or blocked local drainage provisions (Figure 3) and restricted overland flow paths.

These factors may occur in isolation or in combination with each other.

## 3.2. Historical Flood Data

The dates of known major flooding of the Kurnell area:

- 11 Mar 1975 (largest event in recent times),
- 4 Feb 1990,
- 14 Nov 1969,
- 30 Apr 1988,
- 5 Feb 2002,
- 30 Oct 1959,
- 25 Sep 1995,
- 7 Aug 1998,
- 11 Mar 1958,
- 1 May 2001,
- 6 Nov 1984,
- 6 Aug 1986, and
- 13 Dec 1963.

A review of available historical flood level information found that the best available information for recent flood events was the May 2003 event.

The largest recorded tidal event occurred on 25 May 1974, which corresponds with reported tidal flooding in Kurnell.

## 3.3. Design Flood Data

A rainfall-runoff approach was adopted for the determination of design flood levels in the Kurnell catchment, due to the absence of long term historical flood data. This approach involved the setting up of a hydrologic model and a 2D hydrodynamic model.

The Kurnell study area was modelled using the Watershed Bounded Network Model (WBNM) and TUFLOW. WBNM was used to establish a hydrologic model of the upper reaches of the catchment, upstream of the hydraulic model extent. It was used convert rainfall data into flows to be used as upstream inflow boundaries for the hydraulic model. TUFLOW was used to model the hydrology and hydraulics within the hydraulic model extent.

In the absence of comprehensive information for historical events, the models were configured using typical or recommended parameters. A limited process of model validation was then undertaken based on the flood event of May 2003.

Figures 4-7 indicate the hazard classification and design flood heights events for the 1% AEP and PMF event.

## 3.4. Hydraulic Classification

The Floodplain Development Manual (Reference 1) defines three hydraulic categorises which can be applied to define different areas of the floodplain. The hydraulic categories of flood prone land include:

> "*Floodways* are those areas where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels."
>
> "*Flood storage areas* are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood."
>
> "*Flood fringe* is the remaining area of flood prone land after floodway and flood storage areas have been defined."

The above hydraulic classifications have been applied to the Kurnell Township Catchment based on available hydraulic model results together with our knowledge of the catchment and experience in similar catchments. Preliminary maps of hydraulic classification for the 1% AEP and PMF events are provided as Figures 6-7.

## 3.5. Flood Hazard Classification

The provisional hazard categorisation based on depth and velocity for the 1% AEP and PMF event is shown in Figures 6 and 7 respectively, with the flood extents shown on Figures 4 and 5.

True *flood hazard* however, is a measure of the overall adverse effects of flooding. It incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. These factors are not included in the provisional (hydraulic) hazard assessment. In order to determine the true hazard a qualitative assessment based on a number of factors as listed in Table 1 was undertaken. At Kurnell Township, however, these additional factors do not significantly alter the provisional hazard classifications.

Table 1: Hazard Classification

| Criteria | Weight (1) | Comment |
|---|---|---|
| Rate of Rise of Floodwaters | Medium | The rate of rise in the catchment may lead to the town being cut off. rapid, which would not allow time for residents to prepare. |
| Duration of Flooding | Medium | The duration of the event will be a few hours and would not significantly increase the hazard. Post flood drainage will be slow. |
| Effective Flood Access | High | Roads within the catchment can be inundated and may restrict vehicular access during a flood. |
| Size of the Flood | Low | The hazard does not significantly increase with the magnitude of the flood. The town may be cut off for the duration of the flood. |
| Effective Warning and Evacuation Times | High | There is very little, if any, warning time. During the day residents will be aware of the heavy rain but at night (if asleep) residential and non-residential building floors may be inundated with no prior warning. |
| Additional Concerns such as Bank Erosion, Debris, Wind Wave Action | High | The main concern would be debris blocking culverts or pits. This is considered to have a high probability to occur and thus of high impact. |
| Evacuation Difficulties | Low | Given the quick response of the catchment evacuation is not considered to be necessary and therefore is not significant. |
| Flood Awareness of the Community | Medium | The flood awareness of the community is due to frequency and severity of nuisance flooding. |
| Depth and Velocity of Floodwaters | Low | Flow velocities and depths are low |

Note: (1) Relative weighting in assessing the true hazard.

## 3.6. Flood Damages Assessment

### 3.6.1. Background

A flood damages assessment was also undertaken as part of this Floodplain Risk Management Study. The cost of flood damages and the extent of the disruption to the community depends upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land usage and susceptibility to damage,
- awareness of the community to flooding,
- effective warning time,
- the availability of an evacuation plan or damage minimisation program,
- physical factors such as erosion of the river bank, flood borne debris, sedimentation.

Flood damages can be defined as being “tangible” or “intangible”. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value (stress, injury, loss to life, etc.).

Following an assessment of historical property survey and the likelihood of changes to the property it was decided to survey all properties in order to have a consistent database. Each of the 1076 properties was "assigned" a GIS tag which was then used to obtain a flood level for the full range of design flood events. This level was then used with the appropriate formulae and damages curve to determine the tangible property damages for each event.

There are a number of issues with "assigning" a single flood level to a property to estimate flood damages. These include:

- no account is taken of the actual openings where floodwaters could enter a building relative to the applicable flood gradient. Thus a rear door may allow the water to enter rather than the front door,
- the level "assigned" is usually taken as the flood level midway across the property. For areas with low flood gradients this is appropriate, however in "long" properties and factories or areas with strong flood gradients this may not necessarily be appropriate. This is particularly the case in Kurnell. For properties showing unusually high damages costs, locations we digitised in GIS of the front doors and the damages recalculated.
- the "assigned" flood level is only relevant for estimating flood damages and should not be used for development control purposes. These latter levels must be obtained from interpolation of the flood contour maps,

### 3.6.2. Assessment of Tangible Flood Damages

Quantification of tangible flood damages is generally based upon data derived from post-flood damage surveys obtained following historical flood events. An alternative procedure is to undertake a self-assessment survey of the flood liable properties. This latter approach is more expensive and may not accurately reflect what actually occurs in a flood. Floods by their nature are unpredictable and conditions variable. It is therefore unlikely that a self-assessment survey would have predicted the scale or extent of the damages which occurred in Nyngan in 1990 or North Wollongong in August 1998. For this reason it was decided to use the post-flood damage approach in assessing flood damages for the Kurnell study area.

The most comprehensive damage surveys are those carried out for Sydney (Georges River - 1986), Nyngan (1990) and Inverell (1991). Some of the problems in applying data from these studies to other areas can be summarised as follows:

- varying building construction methods, e.g. slab on ground, pier, brick, timber,
- different average age of the buildings in the area,
- the quality of buildings may differ greatly,
- inflation must be taken into account,
- different fixtures within buildings, e.g. air-conditioning units, machinery, etc.,
- change in internal fit out of buildings over the years or in different areas, e.g. more carpets and less linoleum or change in kitchen/bathroom cupboard material,
- external (yard) damages can vary greatly. For example in some areas vehicles can be readily moved whilst in other areas it is not possible,

- different approaches in assessing flood damages. Are the damages assessed on a "replacement" or a "repair and reinstate where possible" basis? Some surveys include structural damage within internal damage whilst others do not,
- varying warning times between communities means that the potential versus actual damage ratio may change significantly,
- variations in flood awareness of the community.

### 3.6.3. Tangible Damages – Residential Properties

Tangible direct damages are generally calculated under the following components:

- Internal,
- Structural,
- External.

Tangible indirect damages can be subdivided into the following groups:

- accommodation and living expenses,
- loss of income,
- clean up activities.

Damages may be calculated as either estimated actual damages or estimated potential damages. If potential damages are calculated an Actual/Potential (A/P) ratio is assigned based upon (as well as other factors) the likely flood awareness of the community and the available warning time.

The flood awareness of the majority of the Kurnell community is likely to be low and the available flood warning time short. However, the raising of goods by a metre onto tables or similar will significantly reduce flood damages as most of the flooding is shallow. Based upon the limited data available it is considered that the A/P ratio for Kurnell would most likely be similar to that applicable at Nyngan and Inverell.

The approach adopted for estimating flood damages was therefore based on that derived from the Nyngan and Inverell flood damages surveys with updating for inflation and the different type of buildings in the catchment.

#### 3.6.3.1. Direct Internal Damages

Internal damages are based upon the following formulae:

$$\frac{D}{D_2} = 0.06 + 1.42H - 0.62H^2 \; for \; H < 1.0m$$

$$\frac{D}{D_2} = 0.75 + 0.12H \; for \; H > 1.0m$$

where,

| | | |
|---|---|---|
| H | = | height of flooding above floor level (m) |
| D | = | damage at height (H) above floor level |
| $D_2$ | = | damage at height of 2 m above floor level |

At Nyngan and Inverell $D_2$ was found to be $12,500 for small houses and $14,500 for medium/large houses. These values are in $1991's. The reference states that "Damages to individual properties scatter widely around the relationship, which can only be used to reliably estimate the aggregated damage to a collection of flood prone dwellings and not the damage to a single dwelling.". Structural damages were not included in the above figures.

Allowing for inflation and differences in the types of buildings and their contents, a $D_2$ value of $60,000 was adopted for this study.

#### 3.6.3.2. Direct Structural Damages

Structural damages were assumed to be a linear relationship from $0 at 0 m to $20,000 at 0.5 m. Above this value it was considered that there would be no additional structural damages.

In floods larger than the 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages have not been included in the analysis.

#### 3.6.3.3. Direct External Damages

External damages (laundry/garage/yard/vehicle) were assumed to be a linear relationship from $0 at 0 m above ground level to $2,000 at 0.5 m. This assumes that the majority of vehicles are moved by residents.

#### 3.6.3.4. Indirect Damages

Indirect damages were assumed to be a linear relationship from $0 at 0 m above floor level to a maximum of $4,000 at 0.5 m.

#### 3.6.3.5. Tangible Damages – Non Residential Properties

Damages to commercial, industrial or public properties cannot be estimated as good as damages to residential properties for a number of reasons, including:

- less post-flood surveys have been undertaken in Australia,
- some properties are insured against flood loss, if this is the case the insurance premiums need to be considered in assessing flood damages,
- flood damages can vary greatly from building to building. For example an electrical retail shop may suffer more damages than say a sandwich shop, as the latter has less high value stock. On the other hand there is more opportunity to reduce this actual damage in the former as the items can be

easily moved by staff if there is sufficient warning and awareness. In large premises the flood damages depends on the care taken in moving stock. Carpets are high value items and cannot be easily moved whilst the cars in a car showroom can generally be easily moved if there is warning,

- the damages can vary from year to year as the usage of a particular premises changes. Damages may also vary on a seasonal or weekly basis depending upon the nature of business,
- indirect damages (loss of trade) may be significant and these are difficult to properly quantify.

For this assessment the damage relationship was assumed to be the same as for residential, except that a multiplier factor was used to reflect the likely increase in damages.

### 3.6.4. Results

The number of buildings inundated above floor level along with the estimated flood damages are summarised for the range of design flood events in Table 2. Table 3 indicates the number of yards inundated.

Table 2: Estimated Flood Damages

| Event | Number of Buildings Inundated above Floor Level | | Total Tangible Flood Damages ($)* |
|---|---|---|---|
| | Residential | Non-Residential | |
| 20% AEP | 40 | 12 | $1,187,234 |
| 5% AEP | 59 | 15 | $1,795,721 |
| 1% AEP | 83 | 17 | $2,505,362 |
| PMF | 459 | 73 | $20,043,314 |
| | | AAD | **$523,758** |

Note: * Excludes all damages to public assets. Includes external damages that may or may not occur with building floor inundation.

Table 3: Number of Properties within Yard Inundation

| | 20% AEP | 5% AEP | 1% AEP | PMF |
|---|---|---|---|---|
| Residential | 607 | 637 | 660 | 698 |
| Commercial | 9 | 9 | 9 | 10 |
| Other * | 64 | 69 | 75 | 91 |
| **Total** | 680 | 715 | 744 | 799 |

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. The Average Annual Damages (AAD) based on the above values is estimated to be $523,758.

### 3.6.5. Results for Climate Change

Table 4 shows the number of buildings inundated above floor level along with the estimated flood damages are summarised for the range a 1% AEP rainfall event with a 10% increase in rainfall and a 100 year ocean level combined with a high sea level rise scenario. The total damages rises by $587,775 and $10,603,876 respectively. A significant increase in the number of properties affected also occurs.

Table 4: Estimated Flood Damages - Climate Change

| Event | Number of Buildings Inundated above Floor Level | | Total Tangible Flood Damages ($)* | Increase in Total Tangible Flood Damages ($)* from base case |
|---|---|---|---|---|
| | Residential | Non-Residential | | |
| 1% AEP (Base case) | 83 | 17 | $2,505,362 | - |
| 1% AEP rainfall with 10% Rainfall Increase | 104 | 23 | $3,093,137 | $587,775 |
| 100 year ocean level with a high (+0.91m) sea level rise | 300 | 66 | $13,109,238 | $10,603,876 |

## 3.7. Previous Flood Mitigation Measures Considered

Whilst a number of different drainage schemes have been developed over the years, these have had varying success, and flooding remains an issue in Kurnell. In some cases, partial implementation of a scheme has had a detrimental effect, such as the creation of localised depressions by partial filling due to the 1957 Blair and Stuckey scheme. The *1980 Revised Drainage Scheme* (Reference 3) provided a number of more appropriate recommendations, some of which have since been implemented. These included the improvement of drainage in the Cook Street area, with the construction of a 375 mm pipe running from Cook Street Swamp to Cook Street. A 1050 mm diameter pipe has also been constructed along the northern side of Captain Cook Drive, adjacent to the National Park. However, the recommendation to fill Cook Street Swamp and provide tidal protection along Balboa and Torres Streets has not been carried out.

## 3.8. Community Consultation

A rigorous public consultation program was carried out as part of this study. This included:

- letter to residents and stakeholders,
- follow up telephone calls to key respondents,
- floodplain management committee meetings,
- workshop/site inspection and interviews,
- public exhibition of material.

# 4. FLOODPLAIN RISK MANAGEMENT MEASURES

## 4.1. Introduction

The NSW Government's *Floodplain Development Manual* (2005) separates floodplain management measures into three broad categories:

**Flood modification measures** modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins and levees.

**Property modification measures** modify land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (zoning) or voluntary purchase.

**Response modification measures** modify the community's response to flood hazard by informing flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

A number of methods are available for judging the relative merits of competing measures. The benefit/cost approach has long been used to quantify the economic worth of each measure on a relative basis enabling ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the Net Present Worth of the reduction in flood damage (benefit) compared to the cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles such as anxiety, risk to life, ill health and other social and environmental effects. In this study the reduction in tangible damages to public utilities as a result of implementation of a floodplain management measure has also not been included.

The potential environmental or social impacts of any proposed flood mitigation measure are of great concern to society and these cannot be evaluated using the classical benefit/cost approach. The public consultation program carried out as part of this study (Section 3.8) has allowed for identifiable social and environmental factors to be considered in the decision making process.

## 4.2. Flood Modification Measures

Flood modification involves changing the behaviour of the flood itself, by reducing flood levels or velocities, or excluding floodwaters from areas under threat. This includes:

- dams,
- retarding basins,
- channel modifications,
- levees,
- flood gates, and
- pumps.

### 4.2.1. Flood Mitigation Dams

Flood mitigation dams have frequently been used in rural areas of NSW to reduce peak flows downstream. Dams are rarely used as a flood mitigation measure for existing development or in urban areas on account of the:

- high cost of construction,
- high environmental damage caused by the construction,
- possible sterilisation of land within the dam area,
- high cost of land purchase,
- risk of failure on the dam wall,
- likely low benefit cost ratio,
- lack of suitable sites. A considerable volume of water needs to be impounded by the dam in order significant reduction in flood level downstream.

Flood mitigation dams are not a practical solution for Kurnell as flooding is caused by overland flow rather than overflow from a major river or creek. Flood mitigation dams were therefore not considered further for this catchment.

### 4.2.2. Retarding Basins

**DESCRIPTION**

Retarding basins are small-scale flood mitigation dams commonly used in urban catchments to reduce downstream peak flows. One of the major impediments in their use as a flood mitigation measure for existing development is the lack of suitable sites. For new “green fields” developments there is the opportunity to incorporate the retarding basins into site design which is not possible for existing development. Retarding basins can also provide significant water quality benefits, though in a heavily built up urban environment it is difficult to maintain these systems for this purpose.

**DISCUSSION**

Similar to the construction of major dams, the effectiveness of retarding basins in reducing peak flows in Kurnell is limited due to the lack of well defined flow paths. In addition, there are no suitable sites for the construction of a retarding basin, as the catchment is highly developed, and areas upstream are either within national park or owned by Caltex Oil Refinery.

Whilst retarding basins appear to be a fairly simple and effective means of controlling runoff and water quality in urban catchments there are a number of potential issues that need to be resolved. These are summarised below.

**Size:** In order to be effective at reducing peak flows and benefiting water quality the basin area must cover a reasonably high percentage of the upstream catchment. The larger the basin, the more effective it will be.

**Cost:** Whilst construction costs of the basin and wall in an urban environment will be high, additional costs are associated with any alterations to services (gas, electricity, telephone, water, sewerage, roads, etc.) that are within or close proximity to the proposed basin. Depending upon the nature of the services these costs may exceed several hundred thousand dollars.

**Benefit:** Whilst any basin will provide some peak flow reductions and water quality benefit this must be balanced against the cost, and whether there are more cost effective methods. For example, it is generally acknowledged that public education and awareness and point source reduction provides the greatest benefit from a water quality perspective. The benefit for peak flow reduction is subject to the size of the basin and the outlet works. These are not easily defined at a concept stage, as detailed survey and design is required. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or significant hazard to mitigate. In large events, basins (unless very big) are largely ineffectual from both a water quality and peak flow reduction perspective. Also, for multi-peaked rainfall events the basin may provide some benefit in the initial peak but very little when the second or third peak arrives.

The use of a basin for dual purposes (water quality and peak flow reduction) generally means that a compromise of the benefits for each purpose has to be reached. This is because the water quality purpose is best achieved by containing all the frequent inflows. For flood mitigation purposes, these flows are generally not contained to allow the volume in the basin to be "empty" at the time of the peak inflow.

**Loss of Land Use:**

In a rural area (or some urban areas) the loss of land for basin construction is acceptable. However in an area such as at Kurnell, where areas of open space are very valuable, the loss of previously useable land (parks) is significant. Basins can have multi-uses but this can be difficult to achieve.

**Safety:** This is one of the most important factors to be considered when constructing a basin in an urban area. Council will be changing an open space area with a low hazard potential during rainfall events to an area with a greater hazard. Apart from the risk of wall failure and consequently a sudden rush of floodwaters, there is the risk that people may drown or be swept into the basin. This can be negated by using fencing but this then precludes the use of the basin for other purposes. Generally basins deeper than say 1.2 m are unacceptable as a person cannot wade out of them. The benefit of a reduction in hazard downstream must be balanced with the potential increase in hazard at the basin site. Constructing a basin places a significant potential liability on Council should it cause harm to persons in flood (or even non-flood) times.

Signs can be placed advising of the hazard, however in a legal environment it is difficult to argue that this abrogates Council's responsibilities. Also children, older residents and non-English speaking background residents may not understand the signs.

**Availability of Land:**

In an urban area the lack of a potential basin site obviously restricts the use of this mitigation measure. The most preferred sites are within golf courses where many of the above issues can be negated.

**Marton Park Wetland**

Aerial photographs and site inspections of the catchment were undertaken to identify potential sites for retarding basins. The only practical location is Marton Park Wetland which provides some flow attenuation for runoff from:

- The national park and Cook Street Swamp via pipe,
- Residential/commercial areas to the north of Marton Park Wetland; and
- The Caltex Oil refinery.

Marton Park Wetland has an area of approximately 120,000 $m^2$. This represents approximately 12.5% of the catchment area. A water level of 0.8 m AHD the wetland has an inundated area of approximately 6600$m^2$. The approximate bank full capacity of the wetland is 45, 000 $m^3$. At a water level of 0.8 m AHD the wetland has a volume of approximately 710$m^3$. In a 5 year event the wetland is overflowing (ie. exceeds bank full capacity), and as such is of limited use as a temporary storage of floodwaters. If the wetland capacity were to be increased to act as a retarding basin this would required substantially increasing its size.

Due to the limited capacity of the swamp, it is likely to have a greater impact on reducing flood levels in surrounding residential areas during smaller, more frequent events. During major flooding, it is unlikely to have a significant impact.

However, ensuring no future filling of the swamp occurs will maximise the capacity of the basin to attenuate floodwaters. Increasing the capacity of the swamp would only be possible by removing the partially constructed earth mound surrounding Marton Park, and lowering the Park itself. There are no other substantial areas of suitable land adjacent to the wetland, and increasing the depth of the wetland would be both costly and have a negative impact on the ecological value of the swamp.

**OUTCOMES**

Retarding Basins are not considered an effective measure to reducing flooding in Kurnell and therefore not a cost effective measure.

**ACTIONS**

No further action.

### 4.2.3. Channel Modifications

**DESCRIPTION**

Channel modifications are usually undertaken to either increase the capacity of the channel and/or improve the conveyance of floodwaters, which in turn will reduce peak flood levels. Channel modifications encompass a broad range of measures and include amplification, straightening, concrete lining, removal of structures, dredging and vegetation clearing.

**DISCUSSION**

The only open channels within the catchment are within Marton Park Wetland adjacent to Solander Street and along Captain Cook Drive. Water flows from the wetland through a culvert under Captain Cook Drive and into the Captain Cook Drive open channel. Flows then enter Quibray Bay north of the electrical substation. The only applicable methods of increasing channel capacity and conveyance are widening the channel and vegetation clearing. These are discussed as follows.

***Amplification and Channel Widening***

Channel amplification would increase the capacity of the creek system and reduce the frequency with which floodwaters overtop the banks. The only clearly defined channels in the catchment are within the Marton Park Wetland. Channel amplification could be taken to increase the capacity of the channel connecting Marton Park Wetland with Quibray Bay.

A preliminary hydraulic assessment of this measure was undertaken using the existing TUFLOW model of the catchment. Assuming the channel was amplified by an additional 4 m in width and 0.5m deep from Marton Park Wetland to Quibray Bay (some 350 m) and doubling the capacity of the culvert under Captain Cook Drive, the maximum reduction in peak flood levels in the 100y ARI Rainfall dominated event is 0.1m in the vicinity of Marton Park wetland. However, only minor widening of the channel would be possible given a major road and housing are located to either side, and hence it is unlikely that the capacity of the channel can be greatly increased. In addition 4 m of open space land is lost along the entire channel length.

***Straightening, Concrete Lining, Dredging and Vegetation Clearing***

These measures are general undertaken in order to increase the conveyance of water through the channel system. However, as the existing open channels at Kurnell are relatively straight and concrete lined these measures are not applicable. Similarly, although these measures would, to varying degrees, assist in reducing flood levels, they are generally no longer advocated due to the significant cost and high environmental, social and/or aesthetic impacts. These measures were not considered further.

***Removal/Replacement of Structures and Blockage Prevention Devices***

Reviews of the August 1998 North Wollongong and June 2007 Newcastle storms highlighted the significant effects blockage of structures can have on flood levels. Evidence from the North Wollongong event indicates that there is the potential for culvert openings less than 6 m width to be partially or fully blocked during a flood.

The effects of blockage were analysed in the Kurnell Township Flood Study (Reference 2) by blocking the pits by 50% and blocking the culvert under Captain Cook Drive. A blockage factor of 50% was considered consistent with the degree of debris observed in pits during site visits as well as documented by residents in the community consultation phase.

While blockage is a major issue in other catchments it makes little difference in Kurnell as the majority of flow is overland flow. Blockage will however reduce the post flood drainage time and water could pond on properties for longer.

**OUTCOMES**

Channel modifications are undertaken as a means to reduce the flood levels by increasing the capacity or conveyance of the system. These are not considered practical in Kurnell. Council should consider further development and enhancing of its maintenance scheme to reduce the likelihood of blockage.

**ACTIONS**

Council to further develop and enhance its maintenance scheme to reduce the likelihood of blockage.

### 4.2.4. Levees, Floodgates and Pumps

**DESCRIPTION**

Levees are built as means of eliminating the inundation of floors and yards during a flood event (up to the design height of the levee together with a freeboard allowance of typically 0.5 m). Flood gates can be considered as a separate modification measure or as part of a levee design. Flood gates allow local waters to be drained from an area when the level of the creek is low but prevent floodwaters from entering (or exiting) when the creek is elevated. Pumps are generally also associated with levee designs. They are installed to remove local floodwaters behind levees when flood gates are closed or there are no flood gates. They are generally only suitable for small volumes of floodwaters and where water ponds in one point. Pumps have a high likelihood of failure (due to loss of power, lack of maintenance etc.).

**DISCUSSION**

Levees are successfully employed on large river systems (Maitland, Lismore, Grafton) where they protect a large number of properties. In an urban area they are more difficult to employ due to the nature of the topography, the high cost and significant social (aesthetics) issues. Examples of nearby levees are at Mackay Park (Marrickville South) on the Cooks River and at Hillcrest Avenue (Bardwell Park) on Bardwell Creek.

A detailed review of likely sites found that the most practical location is along the edge of Quibray Bay to stop tidal inundation.

Whilst flood gates and pumps have been used successfully at a number of locations throughout NSW over many years, they require ongoing maintenance to ensure their continued success. Vandalism, corrosion, damage or vegetation growth can all result in failure at critical times.

Some form of ongoing maintenance program is therefore required. Ensuring the power supply for pumps remains operable during times of flood can also be problematic.

As flooding in Kurnell is caused by overland flow rather than overtopping of a major river or creek line, the construction of levees is not likely to reduce flood levels considerably in a rainfall dominated event. However, the use of levees, floodgates and pumps may be effective in providing some protection against ocean inundation. During high tides, levees could prevent the inundation of areas adjacent to Quibray Bay. Due to the relatively small catchment size of Kurnell, under some circumstances the meteorological conditions causing rainfall are likely to also result in elevated ocean levels. In this situation, a levee may prevent water from the Bay entering, but may also prevent catchment runoff from escaping. Floodgates or pumps would need to be incorporated into the structure to allow catchment runoff to leave the catchment during storm events.

Two options were considered for the levee locations (Figure 9):

- From Prince Charles Parade, along the western side of Ward St, along the edge of Quibray Bay to Captain Cook Drive (approximately 2km)
- The above extended around Marton Park Wetland to high ground near the Oil Refinery (approximately 3.2km)

The above options were considered with and without drop boards in place. Drop boards were placed at the end of roads. The lowering/regrading of Torres, Bridges, and Tasman Street west of Dampier Street and the eastern end of Tasman Street was considered in conjunction it the levee.

In the 1% AEP rainfall dominated extended levee case (with drop boards and lowered roads) flood levels were lowered by 0.06m at the eastern end of Bridge street.

An important issue for Kurnell is the impact of climate change and sea level rise, as areas such as the corner of Balboa and Torres Streets, and at the southern end of Dampier Street are susceptible to ocean inundation. Under future climate change scenarios the levee would prevent the intrusion of ocean inundation. In accordance with State Guidelines (Reference 9) a 0.4m and 0.9m sea level rise scenario was considered. The viability of the levee was tested using a 100 yr rainfall event coupled with sea level rise as well as under current climate conditions.

This resulted in a lowering of flood levels south of Tasman street by up to 0.1m in the extended levee case incorporating dropboards and lowered roads with a 0.9m sea level rise.

Levee options are problematic with some benefits and disadvantages. All model runs assumed perfect operation of the flow control structures which is difficult to achieve. Any levee option would need some pumping included. Pumps are however expensive. The levee provides the most benefit is during an ocean dominated event particularly for the low lying areas adjacent to Quibray Bay. Levees will become more viable as climate change occurs.

While levees provide a range of benefits they also have a number of disadvantages:

- The potential for an increase in the impacts of rainfall dominated flood events,
- The need for ongoing maintenance;
- Loss of land where the levees are constructed;
- Loss of view;
- Require active intervention during a flood.

This structure would cost in the order of $1 Million (excluding the cost of land acquisition and any moving of utilities). Given Council and the Crown own a large portion of land along the proposed levee alignment, the cost of acquiring levee easements may be relatively cheap. While this is an expensive measure it is the only long term viable solution for Kurnell, Ocean levels are predicted to rise 0.9m by 2100 and will continue to rise after this date. Consideration should be given to building it sooner rather than later. A detailed study of the practicality of such as measure needs to be undertaken. If a levee were built it would need to be designed to be raised in the future.

Further consideration of levee construction should consider potential impacts on the environmental particularly aquatic habitats. These impacts are to be avoided and mitigated as far as possible and it is recommended that Council consult with Industry & Investment (I & I) NSW during this process if such impacts are likely.

**OUTCOMES**

Levees, flood gates and pumps could be employed as a floodplain management measure within the catchment. A levee between Prince Charles Parade, along the western side of Ward St, along the edge of Quibray Bay to Captain Cook Drive and around Marton Park wetland would reduce ocean inundation in Kurnell. However, aesthetic, environmental and access issues may make the levee impractical. A detailed study of the practicality of such as measure needs to be undertaken.

**ACTIONS**

The construction of a levee should be investigated by Council.

### 4.2.5. Local Drainage

**DESCRIPTION**

Local drainage is due to excessive runoff which causes local problems such as ponding in low points, inundation of yards, drains blocked, runoff into garages or down driveways.

Local drainage networks are typically designed to remove stormwater during small, frequent rainfall events, and can hence reduce the impacts of nuisance flooding. However, they are generally largely ineffective at reducing flood levels during a major flood due to insufficient capacity.

**DISCUSSION**

Kurnell's drainage system comprises of over 230 drainage pits, including surface inlets, junctions and headwalls; and over 180 links representing underground conduits (circular pipe or box).

Kurnell's flat topography means it is difficult to build a drainage system with sufficient grade to be effective. The lack of grade reduces conveyance and also increases susceptibility to blockage. Extending the drainage network or upgrading/increasing the capacity is therefore unlikely to have a significant impact on flood levels for larger events. A doubling of the pipe capacity was found to decrease flood levels by approximately 0.3m at the corner of Prince Charles Parade and Captain Cook Drive, in a 1% AEP rainfall dominated event. Flood levels are also reduced in the order of 2 or 3 cm over a large portion of Kurnell. With climate change however this measure would allow more water into Kurnell. Pipes fitted with one way valves or flood gates may be an option.

A complete removal of the pipe network (or 100% blockage) would raise flood levels in Marton Park, to the north of Marton Park to Botany bay and east of Marton Park to Dampier Street by 2-3cm. However post flood drainage would be significantly impeded. In the vicinity of Gannon Street flood levels increase by 0.35m.

Local drainage issues will occur during most heavy rainfall events. It is important that Council monitor these issues to determine whether it is a permanent problem that requires a solution or whether it is a temporary problem (e.g. blocked pit or as a result of roadworks) that will be resolved in time (maintenance program).

Sutherland Shire Council maintains a record of flooding and drainage related community complaints. These can be used to identify rainfall events which resulted in flooding in particular areas. The main issues raised by these complaints were insufficient drainage and blocked drains. One resident also experienced flooding problems due to the property being lower than surrounding areas.

**OUTCOMES**

Increasing the pipe capacity while reducing flood levels in the current climate is not considered a viable option in future climates. Local drainage issues will arise from time to time and it is important that Council record all such instances. In order to assess their importance and determine whether a permanent solution is available the local drainage database which Council has used in the past must be maintained and where possible enhanced (photographs).

**ACTIONS**

Council should maintain and where possible improve the existing database of reported local drainage issues and review the required actions following each major rainfall event (say an event of magnitude occurring once or twice a year).

### 4.2.6. Bypass Floodways

**DESCRIPTION**

Bypass floodways are designed to redirect high velocity flows away from critical areas, and reduce flood levels in specific locations. However, they require suitable available land, and can increase downstream flooding by diverting floodwaters away from their natural path. They can also have environmental impacts, and can change channel form.

**DISCUSSION**

**Road Network**

Kurnell was built on a remanent dune system. The development of Kurnell has lead to the altering of flow paths through the addition of fill, buildings and other associated infrastructure. The road network in Kurnell could be regraded to act as a bypass floodway, directing flow away from residential properties. This would require the regrading and lowering of a number of roads. There are currently a number of areas where properties are lower than road level, resulting in floodwaters flowing from the road into residences. Reducing the degree to which this occurs could result in a substantial reduction in flood levels in some locations. Roads would be lowered by up to 0.3m. It would be necessary to maintain some roads which were not used as floodways to enable evacuation to occur.

Potential roads that could be regraded are:

- Torres, Bridges, and Tasman Street west of Dampier Street,
- Balboa Street and
- the eastern end of Tasman Street.

Lowering the road network resulted in a localised decrease in flood levels at the above locations. During a 1% AEP rainfall dominated event flood levels are reduced by 0.11m. This option should be considered in combination with other options.

**Channel**

A review of locations for construction of channels to improve the drainage of floodwaters identified the possibility for construction a channel at the back of houses between Prince Charles Parade and Torres Street.

In order to assess the potential benefits of this measure a 10m wide and 1.5m deep and 350m long was modelled in the existing TUFLOW hydraulic model. This had a very localised effect and is not considered practical.

**OUTCOMES**

Bypass floodways are designed to redirect high velocity flows away from critical areas, and reduce flood levels in specific locations. The road network in Kurnell could be lowered to reduce flood levels however it is not considered cost effective if not used in conjunction with another option.

**ACTIONS**
No further actions.

### 4.2.7. Storm Surge, Wave Runup

**DESCRIPTION**
Properties along Prince Charles Parade and adjacent to Quibray Bay will potentially be affected by high water levels in the Bay as a result of a combination of high tides, storm surge, wave runup in Botany Bay.

**DISCUSSION**
It is possible that damage may occur to the buildings and/or structures (fences, revetment walls) as a result of these factors. The risk is not as high in Kurnell as in other locations because Prince Charles Parade is reasonably high and Quibray Bay is protected. However, the magnitude of these factors has not yet been accurately established and should be assessed at some point in the future.

**OUTCOMES**
While the majority of Kurnell fronts Quibray Bay and has low exposure to storm surge, a separate study is recommended.

**ACTIONS**
A study to assess the magnitude and impact of storm surge, wave runup and other causes of elevated levels in Botany and Quibray Bays should be undertaken.

## 4.3. Response Modification Measures

### 4.3.1. Flood Warning

**DESCRIPTION**
It may be necessary for some residents in the Kurnell catchment to evacuate their homes during a major flood event. The amount of time for evacuation depends on the available warning time. Flood warning, and the implementation of evacuation procedures by the State Emergency Service (SES), are widely used throughout NSW to reduce flood damages and protect lives. The Bureau of Meteorology (BOM) is responsible for flood warnings on major river systems but does not have a system for small creeks and areas with no defined creek network such as Kurnell.

Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services. Adequate flood warning gives residents time to move goods and vehicles above the reach of floodwaters and to evacuate from the immediate area. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding,
- the actual warning time provided before the onset of flooding. This depends on the

adequacy of the information gathering network and the skill and knowledge of the operators,

- the flood awareness of the community responding to a warning.

**DISCUSSION**

Although flood warning has the potential to reduce the social and economic impacts of a flood, it is not possible to develop an effective warning system for a small catchment such as Kurnell. This is due to the relatively short response time from the start of the rain to the time of the flood peak (say less than 2 hours). This may change in the future as the BOM develops more accurate radar based warning systems that can forecast where storms and the consequent flooding will occur. However due to the imprecise nature of weather patterns it is unlikely that a highly accurate system that can provide sufficient warning will ever be possible.

The installation of flood markers, flood signs would assist in residents recognising the problem and these are discussed in Section 4.3.3. Additional data recorders (pluviograph rainfall recorders at Kurnell and water level recorders at Marton Park Wetland) would assist in providing more accurate assessments of the flood problem. However our experience indicates that it may take several years of data collection to obtain valuable data and in that period the cost of gauge maintenance (and possibly replacement) becomes an issue.

The most effective flood warning system for Kurnell would be a local system where each street or group of 20 houses had a leader who phoned or door knocked the houses in that group when significant flooding is expected. This would need to be co-ordinated by an existing community network such as the SES or RFS. While a local SES or RFS would be the preferred option a local sporting club would also work.

**OUTCOMES**

Due to the short response time of Kurnell an effective “traditional” flood warning system is not possible. As advancements in BOM forecasting continues this measure may become more viable. A local flood warning system where locals advise each other of flood risk would be useful.

**ACTIONS**

This measure should be considered further by Council.

### 4.3.2. Evacuation Planning

**DESCRIPTION**

A comprehensive Local Flood Plan, prepared by the SES, would assist in reducing flood damages and the risk to life. Local Flood Plans detail who is responsible for undertaking certain activities before, during and after a flood. This includes information on keeping the community and those involved prepared, how people will be evacuated/reached during a flood, what needs to be undertaken after the flood etc. Flooding in Kurnell is likely to occur in conjunction with flooding at other nearby localities and for this reason SES resources are likely to be stretched and they may not be able to respond to the situation until after the peak has occurred.

**DISCUSSION**

The rate of rise of food waters determines the amount of time the SES has to implement an evacuation plan. The small size of this catchment means the rate of rise is very fast (say less than 2 hours) which means that it would be unlikely the SES would arrive until after the peak (assuming there is no immediate risk to life). Similarly, a flood in Kurnell is likely to occur in conjunction with flooding at other nearby localities which will stretch the resources of the SES. A Local Flood Plan however does address other aspects of flooding, including preparedness and recovery, and for these reasons is still worthwhile to be developed.

Of particular importance for evacuation planning is the Council run childcare centre in Marton Park. This type of facility on the floodplain presents many risks and further work is required to manage them.

Flood waters in Kurnell are generally of a low velocity and hazard risk. While they could be walked through to evacuate, this is not recommended. As flood waters are generally shallow and slow moving (ie. are of a low risk of structurally damaging the house) occupants are best to stay in there houses until the flood waters have receded.

Council should consider in its future planning placing a community hall or facility on high ground eg. facing Prince Charles Parade. During flood events this could be used as an evacuation centre for those who wish to leave their homes. An alternative is an existing facility such as a club house or church. The Botany Bay Field Studies Centre could be used as an evacuation centre. However, the access road to the site is cut off during a minor event and only four wheel drives or SES vehicles would be able to drive through the water at the peak of the flood. The best outcome would be to located an SES facility in the area.

**OUTCOMES**

A Local Flood Plan which includes Kurnell should be prepared. The SES role in flooding on Kurnell is likely to occur before (awareness program) and after the event (clean up) due to the limited response time available and likely demand on resources from other areas flooding concurrently. The community's' response during an event is critical in reducing the flood damages and risk to life and thus, even if emphasised as a 'self help' approach, should be formulated in conjunction with/by the SES.

A detailed evacuation plan (combining flood awareness and preparedness) is required for the childcare facility in Marton Park and Kurnell Public School.

**ACTIONS**

A Local Flood Plan should be prepared as well as a detailed evacuation plan for the childcare facility in Marton Park and Kurnell Public School.

### 4.3.3. Public Information and Raising Flood Awareness

**DESCRIPTION**

The success of any flood warning system (Section 4.3.1) and the evacuation process (Section 4.3.2) depends on:

I. *Flood Awareness:* How aware is the community to the threat of flooding? Has it been adequately informed and educated?

II. *Flood Preparedness:* How prepared is the community to react to the threat? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

III. *Flood Evacuation:* How prepared are the authorities and the residents to evacuate households to minimise damages and the potential risk to life? How will the evacuation be done, where will the evacuees be moved to?

The above can be improved upon through implementation of an effective Council or SES run flood awareness program. The extent of the program can vary from year to year depending upon the circumstances.

**DISCUSSION**

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential risks of the situation. During a period of frequent flooding in other more flood prone areas, the residents would probably have developed an unofficial warning network to effectively respond to imminent danger by raising goods, moving cars, lifting carpets, etc. Photographs and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have “survived” previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner.

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- frequency and impact of previous floods,
- history of residence,
- whether an effective public awareness program has been implemented.

It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and the level of awareness diminishes as the time since the last flood increases. A major hurdle is often convincing residents large floods will occur in the future. Some residents may oppose an awareness program because they consider it reduces the value of their property.

**OUTCOMES**

Based on feedback and general discussions, the residents of Kurnell catchment have a low level of flood awareness and preparedness. This is especially true of younger/newer residents.

A suitable Council wide flood awareness program should be implemented by Council using appropriate elements from Table 5. The details of the program and necessary follow up should be properly documented to ensure that they do not lapse with time and to ensure the most cost effective means of communication.

Table 5: Flood Awareness Methods

| Method | Comment |
|---|---|
| Letter/Pamphlet from Council | These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of subsidies, changes to flood levels or any other relevant information. |
| School Project or Local Historical Society | This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc. |
| Displays at Council Offices, Library, Schools, Shopping Centres, Local Fairs | This is an inexpensive way of informing the community and may be combined with related displays. |
| Historical Flood Markers or Depth Indicators on Roads | Signs or marks can be prominently displayed in parks, on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators on roads advise drivers of potential hazards. |
| Articles in Local Newspapers | Ongoing articles in the newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events make good copy. |
| Collection of Data from Future Floods | Collection of data assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible. |
| Types of Information Available | A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 149 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. |

| Method | Comment |
|---|---|
| Establishment of a Flood Affectation Database | A database would provide information on (say) which houses require evacuation, which roads will be affected (or damaged) and cannot be used for rescue vehicles, which public structures will be affected (e.g. sewage pumps to be switched off, telephone or power cuts). This database should be reviewed after each flood event. It could be developed by various authorities (SES, Police, Council). |
| Flood Preparedness Program | Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this. |
| Foster Community Ownership of the Problem | Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. For example, Council should have a maintenance program to ensure that its drainage systems are regularly maintained. Residents have a responsibility to advise Council if they see a maintenance problem such as a blocked drain that is jammed. This process can be linked to water quality or other water related issues. |

**ACTIONS**

A Flood Awareness Program should be implemented.

## 4.4. Property Modification Measures

### 4.4.1. Flood Planning Levels

**DESCRIPTION**

The flood planning level (FPL) is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings, garages, driveways and even commercial floors as this reduces the frequency and extent of flood damages. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided.

**DISCUSSION**

Sutherland Shire Council has specified the following FPLs in their *Sutherland Shire Development Control Plan 2006* (DCP), however this does not apply to Kurnell. Flood notations are placed on the 149 certificates. The Sydney Regional Environmental Policy 17 - Kurnell Peninsula (1989) applies to Kurnell however, it does not cover flooding. In order to ensure consistency throughout the LGA the same FPLs should be applied whether a Floodplain Risk Management Plan have been completed or not. The only exception would be if the Floodplain Risk Management Plan proposes a change to these FPLs. We understand Council is currently preparing a new Development Control Plan based on the Department of Planning model for the Shire which will include Kurnell. We encourage this move.

The main aim of the FPL's are to reduce the damages experienced by the property owner during a flood. Elevating a house floor level above the FPL will ensure that flood damages are significantly reduced. It is not recommended that the FPL's be applied to garages and carports as this often makes redevelopment of flood prone houses difficult. Given cars can be moved and therefore the damages mitigated, garages should be allowed to flood. Allowing low level garages and carports makes the maintenance of flow paths easier. Areas affected by a flood planning level are shown in Figure 11 while flood risk precincts are shown in Figure 12.

It is recommended that Council further consider the restrict development (either redevelopment or new development) in the critical drainage pathways shown in Figure 10. Restricting development will ensure that these important critical drainage pathways are not blocked and water drains quickly from Kurnell. Within these critical drainage pathways restriction should be placed which does not allow fill within the designated critical drainage pathways area (identified on Figure 10) that restricts the flow path width to less than 3m. Careful consideration should be given to making sure the DCP restrictions and critical drainage pathways locations are not overly restrictive on development, which has been a major concern of residents, without compromising the purpose of the flow paths. To assist in the effectiveness of the flowpaths a pipe will be required from the end of the flow path which ends in the middle of Balboa Street to the bay, given the road is higher than the adjacent properties in this area. This would also assist with drainage of the area in existing conditions. Within the critical drainage paths are some properties which were legitimately filled in the 1970's. In some cases it may be necessary to remove some impediments to flow by regrading some high land to have low points which join to form a flow path.

**OUTCOMES**

In order to ensure consistency throughout the LGA the same FPLs should be applied whether a Floodplain Risk Management Plan have been completed or not. The only exception would be if the Floodplain Risk Management Plan proposes a change to these FPLs. Council is currently updating its Development control plan to include Kurnell. Council should further investigate the potential restriction of development in designated critical drainage pathways and associated drainage works.

**ACTIONS**

A review should be undertaken of suggested upgrades to the FPL policy.

### 4.4.2. Development Control Planning

**DESCRIPTION**

Within the Kurnell catchment there is continuing pressures for both redevelopment of existing buildings as well as for new development. The strategic assessment of flood risk can prevent development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new or redeveloped properties likely to be affected by flooding to acceptable levels.

**DISCUSSION**

At present, development in flood liable areas is not addressed in the current *Sutherland Shire Development Control Plan 2006 (DCP).*

These policies set guidelines for minimum levels of habitable floors, garages, basements and driveways as well as detailing other considerations (such as overland flow paths, affect on surrounding properties, OSD, etc.). The policies govern only if the area of interest has not already been addressed in a Floodplain Risk Management Plan. This approach was adopted to ensure that those flood-affected properties not yet subjected to a Floodplain Risk Management Plan still have appropriate planning controls applied.

In order to provide a more substantial level of control it is essential that the objectives are stated in the Local Environmental Plan (LEP). If included in the LEP the guiding principles of development in flood-liable land are ensured of being adhered too. We note that Council has words relating to flooding in their LEP and promote the updating of the document.

A review of the *Sutherland Shire Development Control Plan 2006* was undertaken and it is noted that all key features of such policies are included. However the success of these policies can only be determined once implemented and specific problems/issues addressed as they arise.

A key issue is that Council "tags" all such flood affected properties on their 149 certificates. This can readily be accomplished using the results from the Flood Study (Reference 2). For residential properties, land up to the FPL should be tagged to ensure that buildings on land just above (less than 0.5 m) the 100y ARI level will be subject to flood related development controls.

Council's OSD policy reflects current best practice. However Council should give consideration to:

- allowing a payment in lieu contribution in exceptional cases,
- ensuring all OSDs are included in a GIS database.

**OUTCOMES**

A review of Council's current development control planning indicates that development controls and planning for flood liable land have been formalised by Council in either Floodplain Risk Management Plans or *Sutherland Shire Development Control Plan 2006*. We understand that Council's Local Environmental Plan (LEP) is to be updated. While flooding is covered in the current LEP we encourage the use of stronger words relating to flooding. Inclusion in Council's LEP is necessary to ensure that the controls can be enforced. We recommend the updating of the DCP for the whole LGA to include climate change using the results from the Kurnell Flood Study (Reference 2) and other similar studies.

In addition, the following issues should be considered:

- procedure for "tagging" properties,
- consideration within Council's OSD approach for:
    - payment in lieu,
    - inclusion on database.

**ACTIONS**

Council is encouraged to update its DCP for the whole LGA.
Council should review this document after a significant flood event, a change in policy or 5 years after adoption of this report.

### 4.4.3. House Raising

**DESCRIPTION**

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. This approach provides more flexibility in planning, funding and implementation than voluntary purchase. However its application is limited as it is not suitable for all building types and only becomes economically viable when above floor inundation occurs frequently (say in a 10y ARI event or less).

**DISCUSSION**

House raising is suitable for most non-brick single storey buildings on piers and is particularly relevant to those situated in low hazard areas on the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. However it does not reduce the external hazard, evacuation issues or yard/garage damages. Within the Kurnell catchment 15 properties were identified which have building materials potentially suitable for house raising. Ten of these are inundated in events smaller than the 1% AEP event.

The cost of raising eligible houses is approximately $50,000 per building. This option is not considered feasible and has a benefit cost ratio of 0.6.

**OUTCOMES**

Based on the above estimated benefit-cost ratios, it is suggested that the option of house raising is not feasible.

**ACTIONS**

No further action.

### 4.4.4. Voluntary House Purchase

**DESCRIPTION**

Voluntary purchase involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain. Generally the land is returned to open space, however there may be an opportunity for a new house to be built at a higher floor level, either on fill or on a higher part of the property.

**DISCUSSION**

Voluntary purchase is mainly implemented in high hazard areas over a long period as a means of removing isolated or remaining buildings and thus freeing both residents and potential rescuers from the danger and cost of future floods. It also helps to restore the hydraulic capacity of the floodplain (storage volume and waterway area).

Voluntary purchase has no environmental impacts although the economic cost and social impacts can be high. Many residents do not accept voluntary purchase because it would have significant impact on their community and way of life. Among these concerns are:

- it can be difficult to establish a market value that is acceptable to both the State Valuation Office and the resident,
- in many cases residents may not wish to move for a reasonable purchase price,
- progressive removal of properties may impose stress on the social fabric of an area,
- it may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values or features.

A voluntary purchase scheme is not considered necessary in Kurnell given that no properties are at extreme risk of high velocities or loss of life. However, voluntary purchase should be maintained as an option where the purchase of a house is required to build flood mitigation works. The inclusion of properties in a voluntary purchase scheme requires careful consideration and discussion between the affected residents and Council.

**OUTCOMES**

A voluntary purchase scheme is not considered necessary in Kurnell given that no properties are at extreme risk of high velocities or loss of life. This option should only be considered if the houses need to be removed to restore flow paths.

**ACTIONS**

No further action.

### 4.4.5. Flood Proofing

**DESCRIPTION**

Flood proofing where building are designed to be sealed up to exclude the entry off flood waters or are built of flood compatible materials that are not damaged by flood waters and can be early cleaned up. It is generally only suitable for brick buildings with concrete floors and it can prevent ingress for outside water depths up to approximately one metre. Depending on the nature of construction, greater depths may cause structural problems (buoyancy) unless water is allowed to enter.

**DISCUSSION**

Flood proofing involves the sealing of entrances, windows, vents etc. to prevent or limit the ingress of floodwater. It is generally only suitable for brick buildings with concrete floors and it can prevent ingress for outside water depths up to approximately one metre. Depending on the nature of construction, greater depths may cause structural problems (buoyancy) unless water is allowed to enter.

This measure is rarely used in NSW for residential buildings and is more suitable to commercial premises where there are only one or two entrances and maintenance and operation procedures can be better enforced.

For the commercial properties within the Kurnell catchment, this would require sealing the doors and possibly windows (new frame, seal and door); sealing and re-routing of ventilation gaps in brickworks; sealing of all underfloor entrances; checking of brickwork to ensure that there are no gaps or weaknesses in the mortar and sealing of floor wastes and toilets.

Flood proofing would not reduce the flood hazard. There are no significant environmental or social problems.

There are sophisticated flood proofing measures available such as “pop up” flood gates and “removable gates”. However it is doubtful if these measures could be economically justified as the last time major flooding occurred was over 30 years ago (March 1975).

**OUTCOMES**

Flood proofing for the flood affected non-residential buildings would assist in reducing the tangible damages associated with flooding in the catchment. This measure is unlikely to receive Government funding however it should still be pursued by Council. Potential owners should be advised that it is an available option.

**ACTIONS**

Flood proofing should be promoted as a means available to reduce flood damages for non-residential buildings.

# 5. DEVELOPMENT MEASURES

This chapter discusses the management of future development from a flooding and water quality perspective.

## 5.1. Climate Change

**DESCRIPTION**

The earth's surface temperature is due to the presence of certain gases in the atmosphere which allow the sun's rays to penetrate to the earth but reduce the amount of energy being radiated back. It is this trapping of the reflected heat which has enabled life to exist on earth.

Since the early 1980's there has been concern that increasing amounts of greenhouse gases (water vapour, carbon dioxide, methane, nitrous oxide, ozone) resulting from human activity may be raising the average earth surface temperature. As a consequence, this may affect the climate and sea level. The extent of any permanent climatic or sea level change can only be established through scientific observations over several decades. Nevertheless, it is prudent to consider the possible range of impacts with regard to flooding and the level of flood protection provided by any mitigation works.

Based on the latest (2007) research by the United Nations Intergovernmental Panel on Climate Change (Reference 7) evidence is emerging on the likelihood of climate change and sea level rise as a result of increasing "greenhouse" gasses. In this regard, the following points can be made:

- greenhouse gas concentrations continue to increase,
- the balance of evidence suggests human interference has resulted in climate change over the past century,
- global sea level has risen about 0.1 m to 0.25 m in the past century,
- many uncertainties limit the accuracy to which future climate change and sea level rises can be projected and predicted.

The best available estimate of the projected sea level rise (including ice melt - Reference 8) along the NSW coast is from 0.18 m to 0.91 m between the years 2090 and 2100.

**DISCUSSION**

The Bureau of Meteorology along with Engineers Australia are currently investigating revising design rainfalls to take account of the potential climate change. However, the possible mechanisms are far from clear, and there is no certainty that the changes would in fact increase design rainfalls for major flood producing storms. Even if an increase in total annual rainfall does occur, the impact on design rainfalls may not be adverse. There is some recent literature by CSIRO that suggests rainfalls may increase by up to 30% in parts of NSW (in other places the increases are much less), however this information is not of sufficient accuracy for use as yet.

Any change in design flood rainfall intensities will increase the frequency, depth and extent of inundation across the catchment. It has also been suggested that the cyclone belt may move further southwards. The possible impacts of this on design rainfalls cannot be ascertained at this time as little is known about the mechanisms that determine the movement of cyclones under existing conditions.

The issue of sea level rise is complicated by other long term influences on mean sea level changes. The NSW Government has adopted a sea level rise of 40 cm by 2050 and 90 cm by 2100 (Reference 9).

The Kurnell Flood Study (Reference 2) considered the potential impacts of climate change on both ocean (sea level rise) and catchment flooding (an increase in rainfall intensity) separately, as well as the combined effects. The sensitivity of both the 20% and 1% AEP events to climate change has been modelled to provide an indication of the magnitude of impacts for both smaller, more frequent flood events as well as major events. Kurnell has extreme susceptibility to climate change. An increase in rainfall and ocean levels will both have detrimental impacts. The dominate flooding mechanism in many areas will swap from rainfall to ocean inundation. The lowest lying houses in Kurnell will be inundated prior to 2050 by the highest tide of the year. Any management issues adopted for Kurnell should consider current and future climates.

Some Council's in NSW have raised the Flood Planning Levels (FPL) to account for the expected increase in flood level. This rise would be in addition to the 0.5 m freeboard. Sea level rise should be incorporated into the FPL for those houses in Kurnell which will be affected by it according to the results of the modelling undertaken as part of the Kurnell Flood Study (Reference 2). This issue should be canvassed with development of an LGA wide policy on climate change.

Council should continue to monitor the available literature and reassess Council's Flood Policy as appropriate. At a minimum Council should obtain the most current information available from the Bureau of Meteorology and DECCW every two years.

**ACTIONS**

Any management issues adopted for Kurnell should consider current and future climates. Some Council's in NSW have raised the Flood Planning Levels to account for the expected increase in flood level. This rise would be in addition to the 0.5 m freeboard. For new development the Flood planning level should be based on the 100yr flood levels incorporating the 2050 climate change scenario (0.4m sea level rise), with 0.5m freeboard (Figure 11 indicates areas subject to Flood planning levels/controls). This issue should be canvassed with development of an LGA wide policy on climate change.

Council should continue to monitor the available literature and reassess Council's Flood Policy as appropriate.

## 5.2. Development Intensification

**DESCRIPTION**

There is continuing pressure on Council to permit further subdivision of existing lots to increase the density of development within the catchment. As a result this could increase water quality issues and/or exacerbate flooding.

**DISCUSSION**

Water quality issues are becoming increasingly important and Government bodies are encouraging people to minimise pollution, recycle materials and not dispose of harmful material to our drainage systems. Whilst these impacts will have no significant impact upon flood levels, community awareness and acceptance of these issues will assist in a better appreciation of other water related and environmental matters. It is hoped that this will provoke a more pro-active solution to the problem rather than an adversarial developer versus Council position.

Council has already constructed gross pollutant traps. The cost of these structures is much reduced if they can be incorporated into redevelopment of an area rather than retro-fitted. Increased public awareness of these issues (TV, radio, newspaper, Council notices) will assist in reducing the problem.

Filling of low lying land is generally undertaken for a new development to raise the level of a building pad to ensure that the floor level is above the flood planning level. If the land is within the floodplain it can result in:

- the loss of temporary floodplain storage which could cause an increase in peak flow and flood level downstream,
- the loss of available flow path which could result in an increase in flood level upstream,
- redirection of local runoff onto adjoining properties.

Many of the blocks in Kurnell are large and thus there is little potential for a significant amount of filling to occur. Historical filling of lots in Kurnell has caused the redirection of local runoff onto adjoining properties.

**OUTCOMES**

Future development has the potential to increase water quality problems. However Council has in place policies to negate any increase and together with a public awareness program and construction of water quality devices the water quality of the catchment should be improving. Works or filling on the floodplain has the potential to adversely affect flood levels. Council already has policies in place to ensure that flooding is considered as part of the Development Application process. However it is appropriate that this study provides guidelines that can be included in any updated policies. The following are proposed:

- any development which is proposed within the 100 year ARI flood extent must consider the potential impacts of the works on flood levels,
- proposed works on private lands within the 100 year ARI flood extent need NOT consider the potential impacts of the works on available flow paths (for flooding of the main channel but not necessarily overland flow) through the property. The loss of temporary floodplain storage should only be considered

if the cumulative area to be lost since 2009 is greater than 10 $m^2$,

- proposed works greater than 10 $m^2$ on public lands within the 100 year ARI flood extent must have a Flood Study undertaken by a professional engineer experienced in floodplain management. The nature and extent of the Flood Study will be determined by the engineer at the time.

**ACTIONS**

The existing water quality policies of Council are supported. Council policies to manage the adverse effects of development on flooding are to be amended to include the proposed guidelines.

## 5.3. Water Sensitive Urban Design

### 5.3.1. Background

Urban development can lead to changes in the catchment hydrology, with the most obvious being an increase in peak flow (and resulting flood levels) and pollutants witihin the system. Traditionally floodplain risk management studies have focussed on the increase in peak flow where the principal objective is to safely and efficiently convey stormwater to the ocean.

The increased public awareness of environmental issues and shortage of water resources have highlighted the importance of the environmental management of urban stormwater. An integrated stormwater management strategy to cater for multiple objectives is therefore required. This approach is termed Water Sensitive Urban Design (WSUD) and has the following broad objectives:

- reduce the potable water demand through water efficient appliances and rainwater and grey water collection and reuse,
- minimising wastewater generation,
- treat urban stormwater to meet water quality objectives and reuse if possible,
- using stormwater to maximise the visual and recreational amenity of the urban landscape.

This floodplain risk management study supports the general objectives of WSUD but it is not possible to address every aspect (e.g. water saving devices, grey water reuse, etc.) within the scope of the study. The following sections consider those aspects that can be included within the scope of the NSW Government’s Floodplain Development Manual (Reference 1).

### 5.3.2. Reduce Potable Water Demand

The introduction of BASIX (Building Sustainability Index) to ensure minimum energy and water use targets has ensured that all new developments minimise the potable water demand. One outcome of this is the maximisation of pervious area within a development thus reducing the volume and rate of runoff during a flood event. A major consequence will ultimately be a slowing down (or at least not an increase) of the rate of runoff and thus the peak flow.

Whilst BASIX only applies to residential developments the water use principles can also be applied to other land use activities. However this could also be further extended to existing Council or government structures and facilities.

In some Council areas there are opportunities to construct either rainwater tanks or structures, for example on concrete netball or tennis courts. Inspection of the catchment indicates no obvious or significant facilities where this approach could be applied. However should such an opportunity arise this should be supported.

### 5.3.3. Minimise Waste Generation

There is no opportunity within the scope of this study to address this aspect of WSUD.

### 5.3.4. Treat Urban Stormwater

**Gross Pollutant Traps:** There is the opportunity to install a GPT (Gross Pollutant Trap) at the inflow points to Marton Park Wetland (particularly Cook Street) and Botany Bay. The installation of GPT's within the catchment was promoted by the *Marton Park Wetland Plan of Management* (Reference 6). This would be an offline structure. Constructing it as part of a wetland would incorporate a nutrient absorption function. The cost of this structure may be $200,000. It would provide significant environmental benefit with no adverse hydraulic impacts and potentially some social benefits.

These activities may involve the harm of marine vegetation or dredging and reclamation activities and require a permit from this Department. I&I NSW recommend that Council consult further to determine what approvals will be necessary when these works are being planned.

There may be other potential sites of GPTs. These should be considered where appropriate.

**Sub-Surface Devices:** Where appropriate Council should install these devices. A major consideration with these devices is the ongoing maintenance. This is costly and if not undertaken regularly means the device is largely ineffective.

**Improved Water Absorption:** Council should consider, as far as possible, changes to its work procedures to ensure maximum water absorption. For example this may mean grading footpaths or similar so they shed runoff onto grassed areas before entering the stormwater system. On public roads this is generally not possible but could be implemented within certain types of developments (units).

**Maximisation of Visual and Recreational Amenity:** Achieving the objective of enhancing the visual and recreational amenity is outside the scope of the present study.

# 6. ACKNOWLEDGEMENTS

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- Sutherland Shire Council,
- Kurnell Floodplain Risk Management Committee,
- NSW Department of Environment Climate Change and Water.

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# Figures

# Appendix A

# APPENDIX A: GLOSSARY

## Taken from the Floodplain Development Manual (April 2005 edition)

**acid sulfate soils**
Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.

**Annual Exceedance Probability (AEP)**
The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 $m^3/s$ has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 $m^3/s$ or larger event occurring in any one year (see ARI).

**Australian Height Datum (AHD)**
A common national surface level datum approximately corresponding to mean sea level.

**Average Annual Damage (AAD)**
Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.

**Average Recurrence Interval (ARI)**
The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

**caravan and moveable home parks**
Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.

**catchment**
The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

**consent authority**
The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.

**development**
Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act).

**infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

**new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

**redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

**disaster plan (DISPLAN)**
A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

**discharge**
The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second ($m^3$/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

**ecologically sustainable development (ESD)**
Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.

**effective warning time**
The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

**emergency management**
A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

**flash flooding**
Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

**flood**
Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

**flood awareness**
Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

**flood education**
Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

**flood fringe areas**
The remaining area of flood prone land after floodway and flood storage areas have been defined.

**flood liable land**
Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).

| | |
|---|---|
| **flood mitigation standard** | The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding. |
| **floodplain** | Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land. |
| **floodplain risk management options** | The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options. |
| **floodplain risk management plan** | A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives. |
| **flood plan (local)** | A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service. |
| **flood planning area** | The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the “flood liable land” concept in the 1986 Manual. |
| **Flood Planning Levels (FPLs)** | FPL’s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the “standard flood event” in the 1986 manual. |
| **flood proofing** | A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages. |
| **flood prone land** | Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land. |
| **flood readiness** | Flood readiness is an ability to react within the effective warning time. |
| **flood risk** | Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.<br><br>**existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain.<br><br>**future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain.<br><br>**continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure. |

**flood storage areas**
Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

**floodway areas**
Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

**freeboard**
Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

**habitable room**
**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

**in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

**hazard**
A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

**hydraulics**
Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

**hydrograph**
A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

**hydrology**
Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

**local overland flooding**
Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

**local drainage**
Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

**mainstream flooding**
Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

**major drainage**
Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

**mathematical/computer models**

The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

**merit approach**

The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

**minor, moderate and major flooding**

Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

**minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

**moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

**major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

**modification measures**

Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

**peak discharge**

The maximum discharge occurring during a flood event.

**Probable Maximum Flood (PMF)**

The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

| | |
|---|---|
| **Probable Maximum Precipitation (PMP)** | The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation. |
| **probability** | A statistical measure of the expected chance of flooding (see AEP). |
| **risk** | Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment. |
| **runoff** | The amount of rainfall which actually ends up as streamflow, also known as rainfall excess. |
| **stage** | Equivalent to "water level". Both are measured with reference to a specified datum. |
| **stage hydrograph** | A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum. |
| **survey plan** | A plan prepared by a registered surveyor. |
| **water surface profile** | A graph showing the flood stage at any given location along a watercourse at a particular time. |
| **wind fetch** | The horizontal distance in the direction of wind over which wind waves are generated. |

# Appendix B

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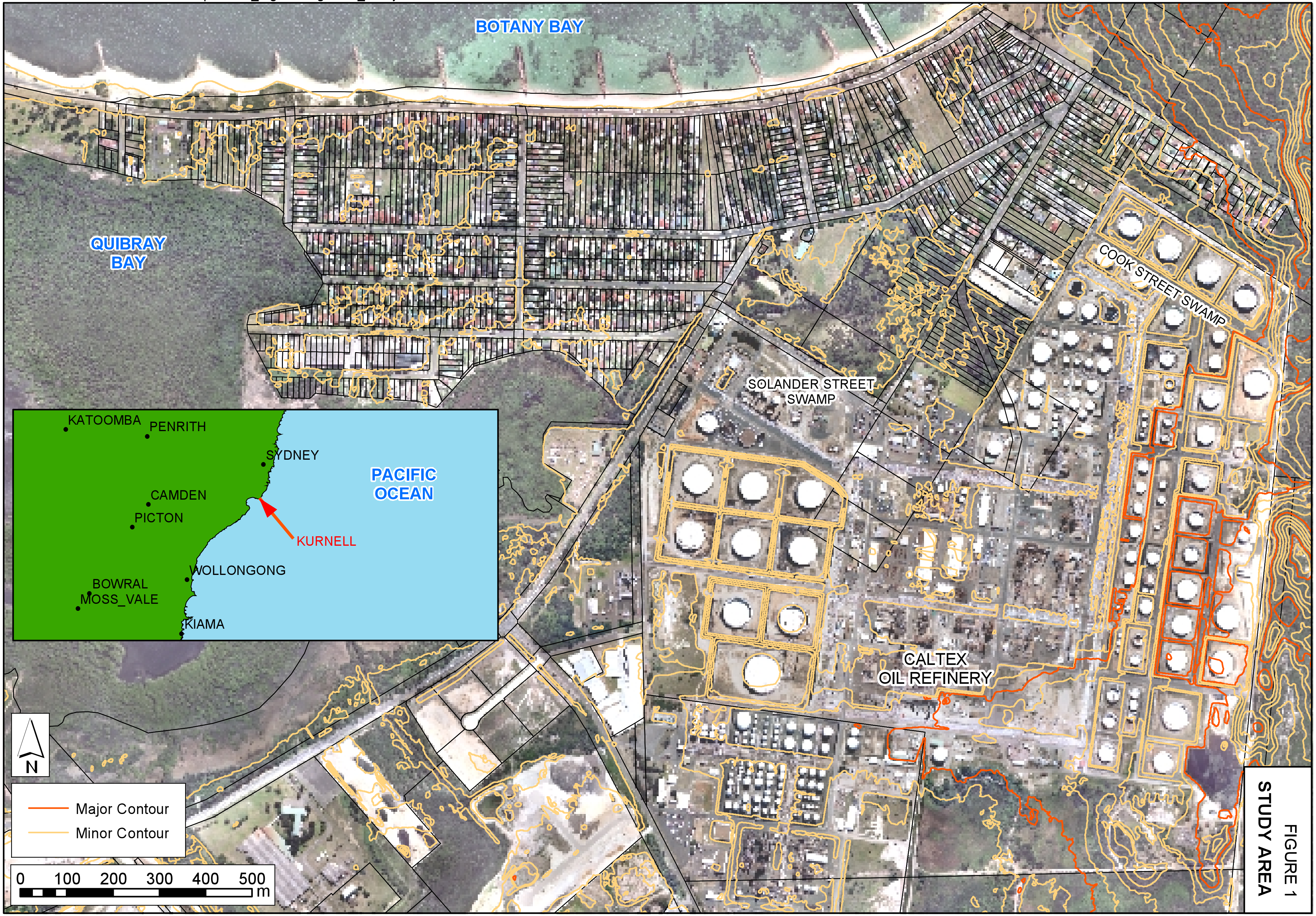


FIGURE 1
STUDY AREA

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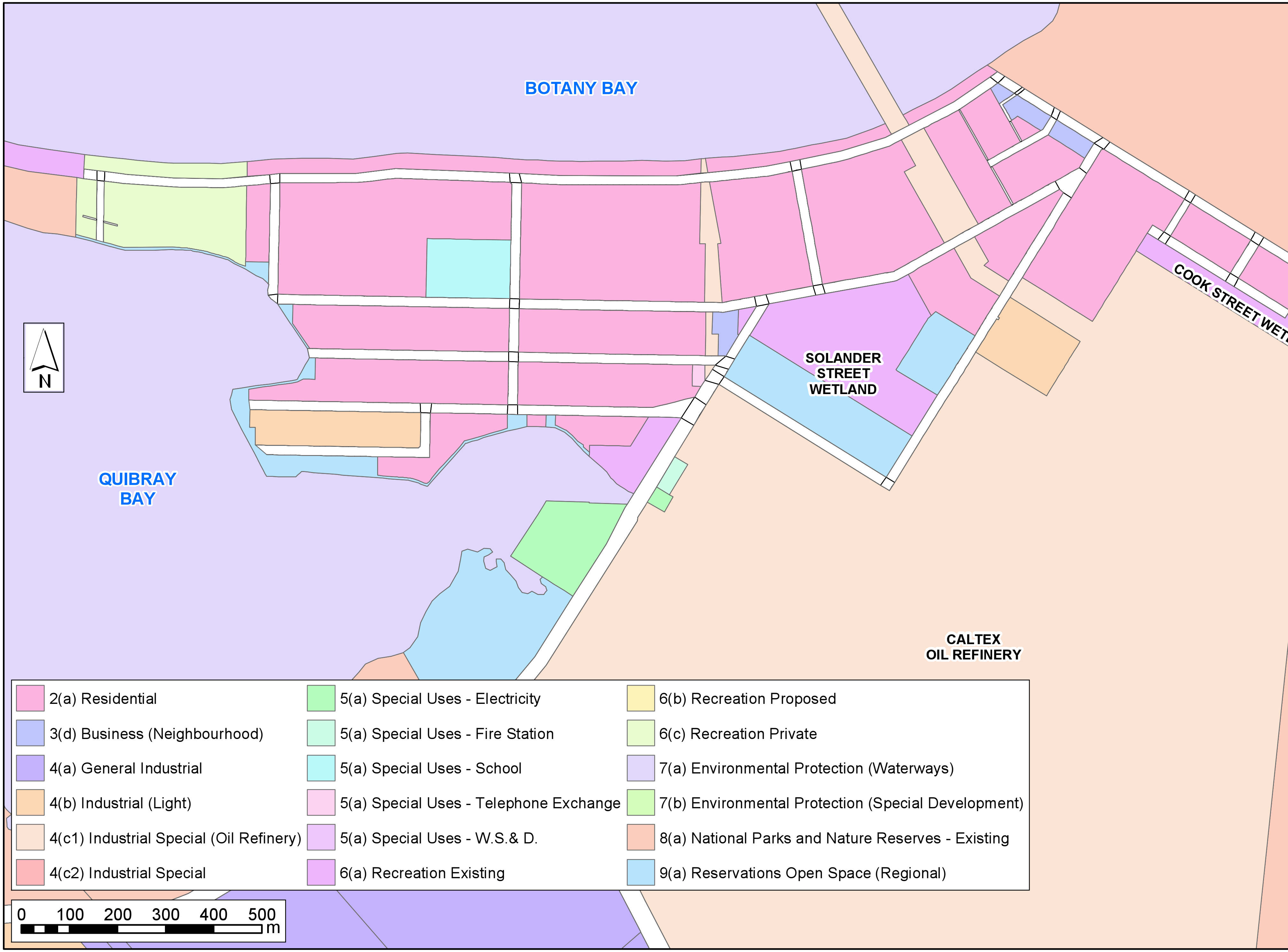


FIGURE 2
LEP ZONES

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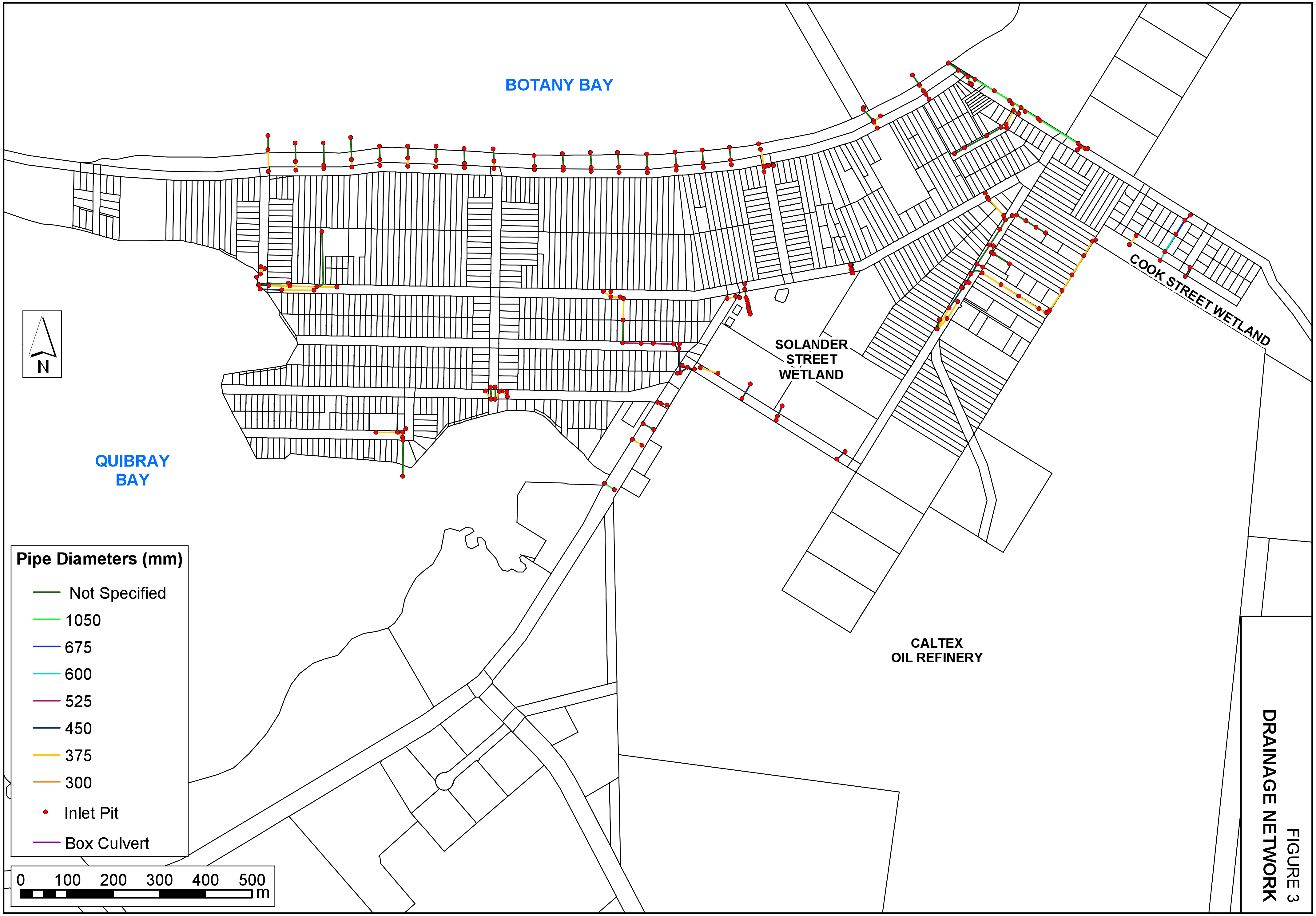


FIGURE 3
DRAINAGE NETWORK


FIGURE 4
PEAK FLOOD LEVELS
1% AEP EVENT
BOTANY BAY
BOTANY BAY
NATIONAL PARK
Prince Charles Pde
Prince Charles Pde
CALTEX
OIL REFINERY
QUIBRAY
BAY
N
Limit of Flood Mapping
Peak Flood Level (mAHD)
<1
1- 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 4
4 - 5
>5
0 100 200 300 400 500
m
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FIGURE 5
PEAK FLOOD LEVELS
PMF EVENT

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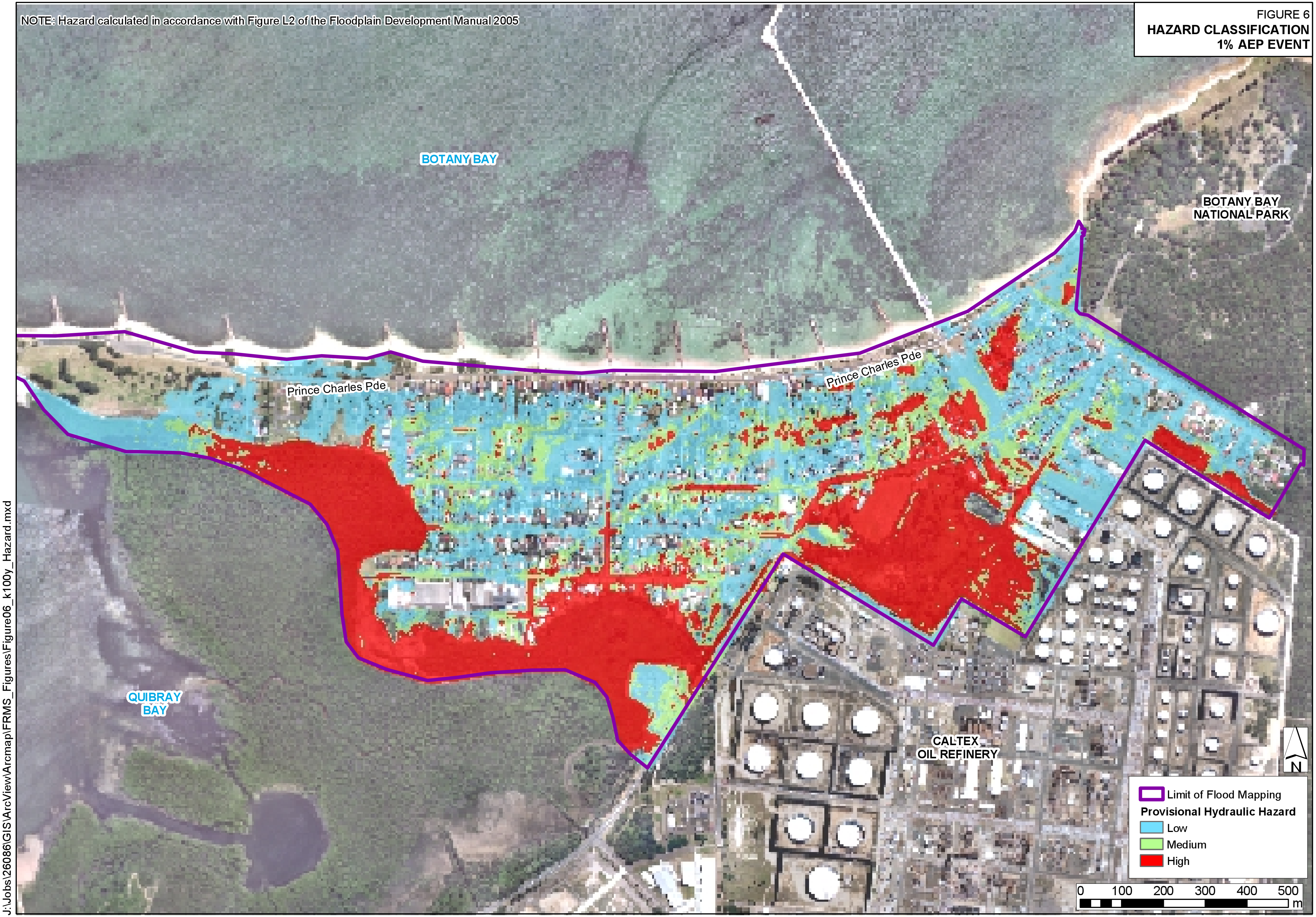

NOTE: Hazard calculated in accordance with Figure L2 of the Floodplain Development Manual 2005
FIGURE 6
HAZARD CLASSIFICATION
1% AEP EVENT
BOTANY BAY
BOTANY BAY
NATIONAL PARK
Prince Charles Pde
Prince Charles Pde
QUIBRAY
BAY
CALTEX
OIL REFINERY
N
Limit of Flood Mapping
Provisional Hydraulic Hazard
Low
Medium
High
0 100 200 300 400 500
m
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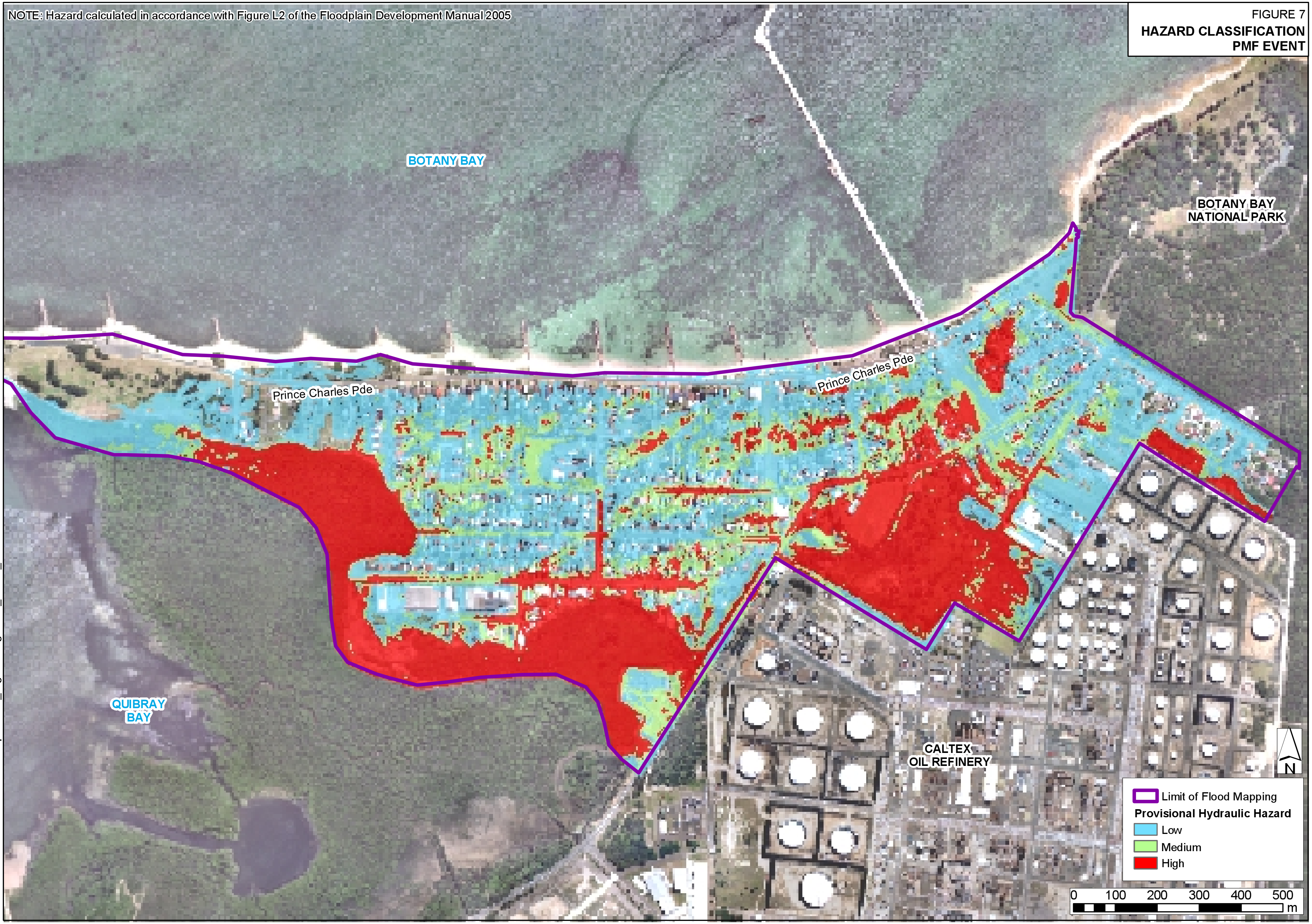


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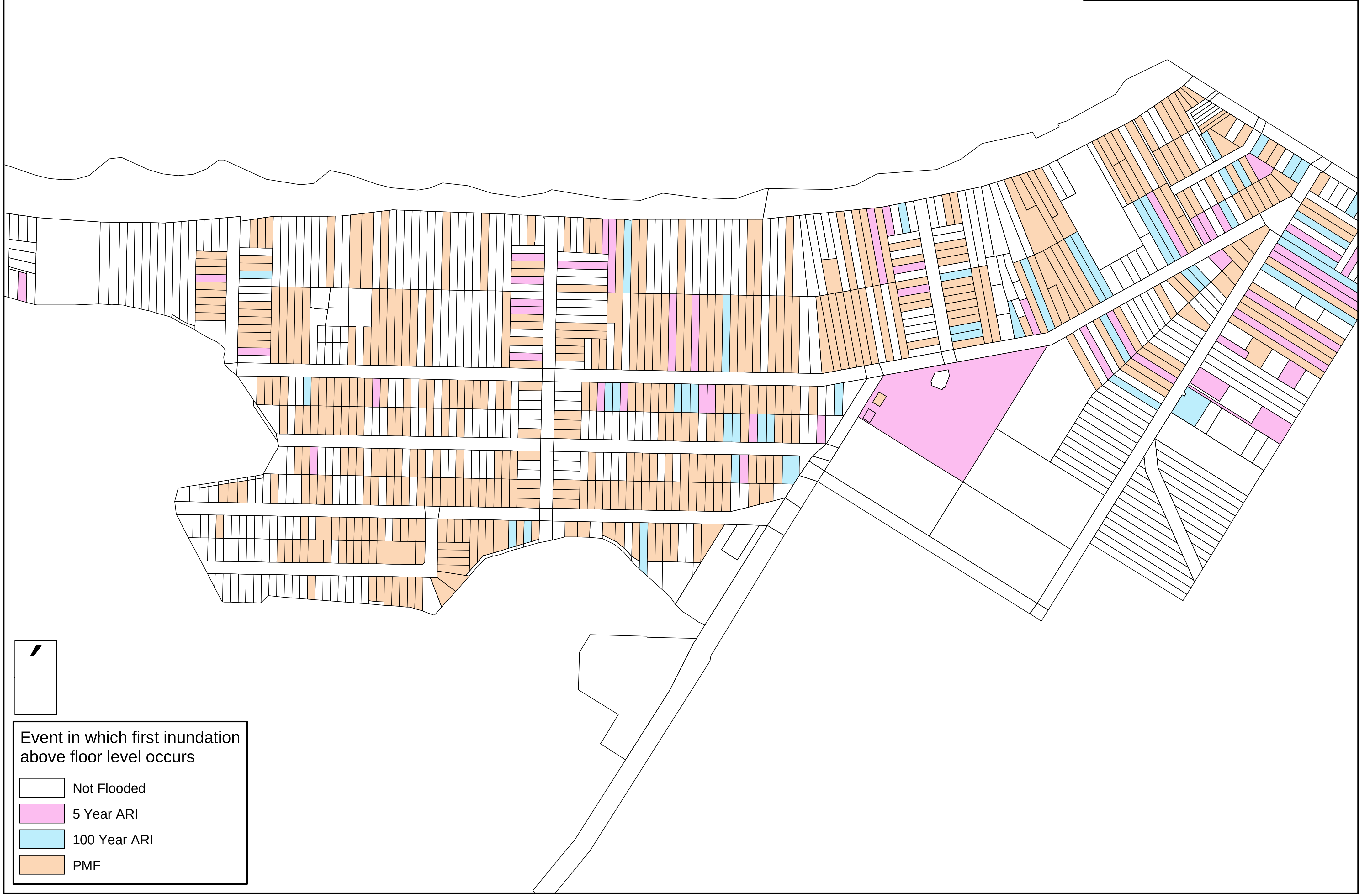
FIGURE 8
**FLOOD LIABLE BUILDINGS**



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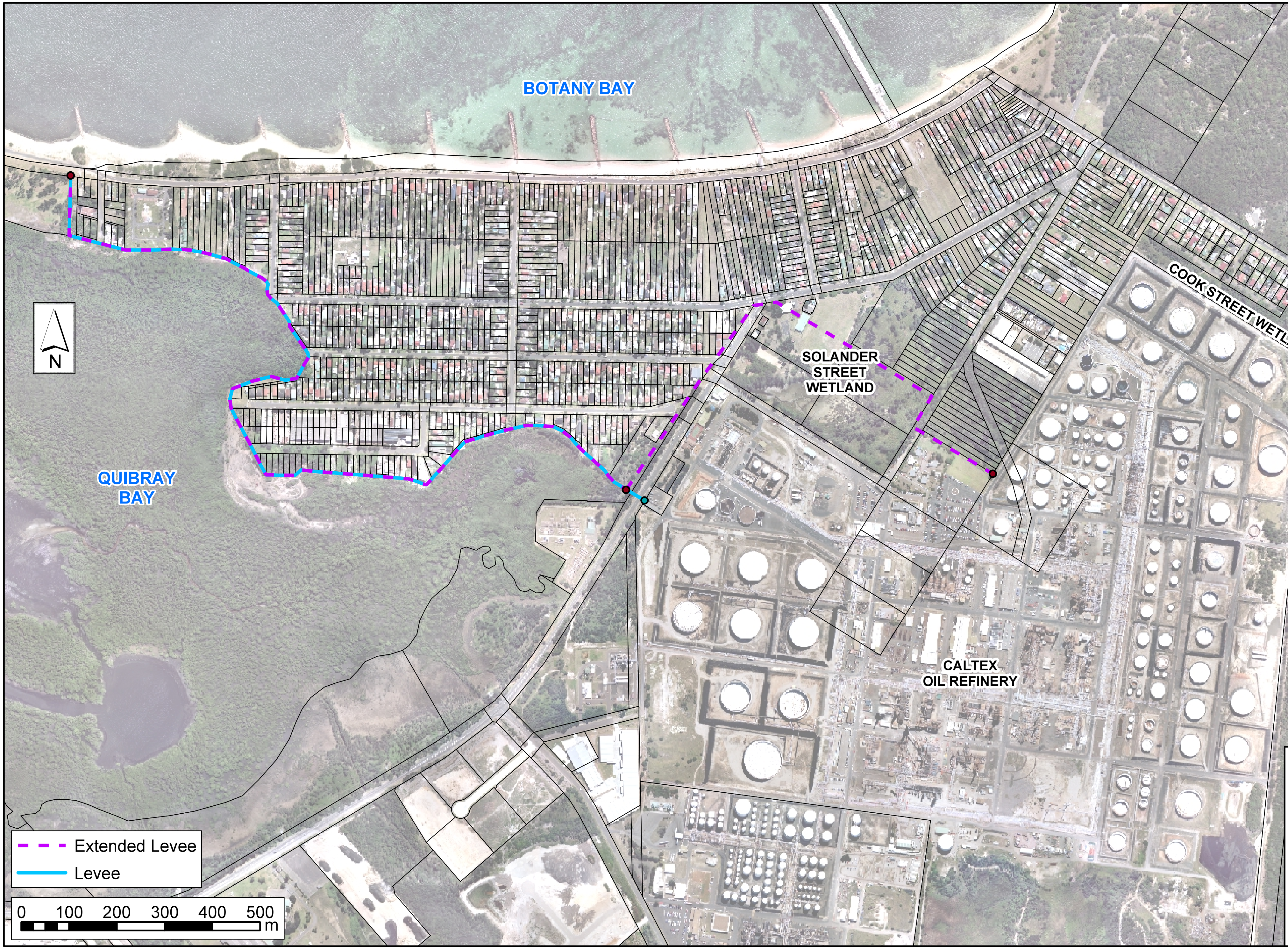


FIGURE 9
POTENTIAL LEVEE LOCATION

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FIGURE 10
CRITICAL DRAINAGE PATHWAYS

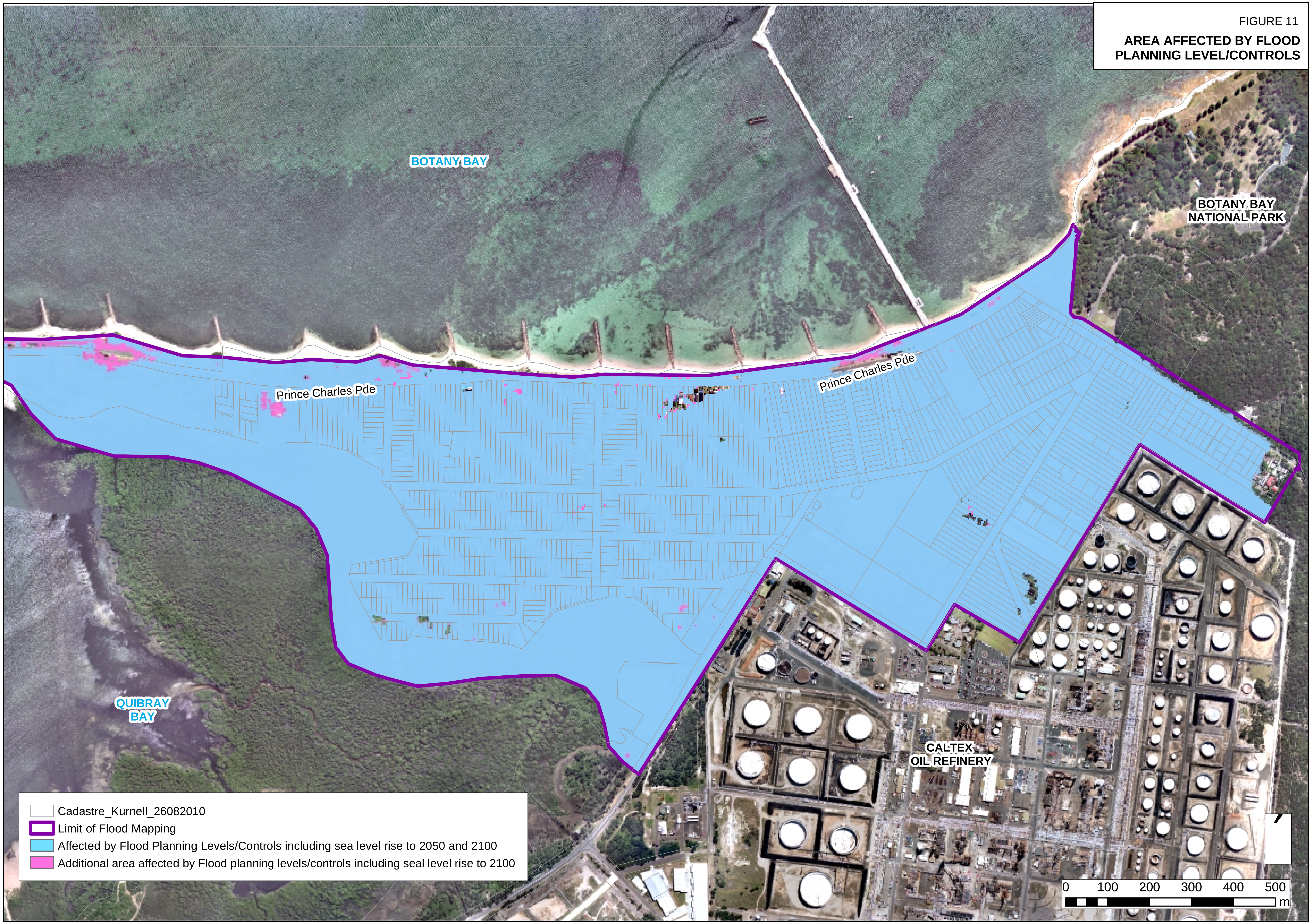


FIGURE 11

**AREA AFFECTED BY FLOOD PLANNING LEVEL/CONTROLS**

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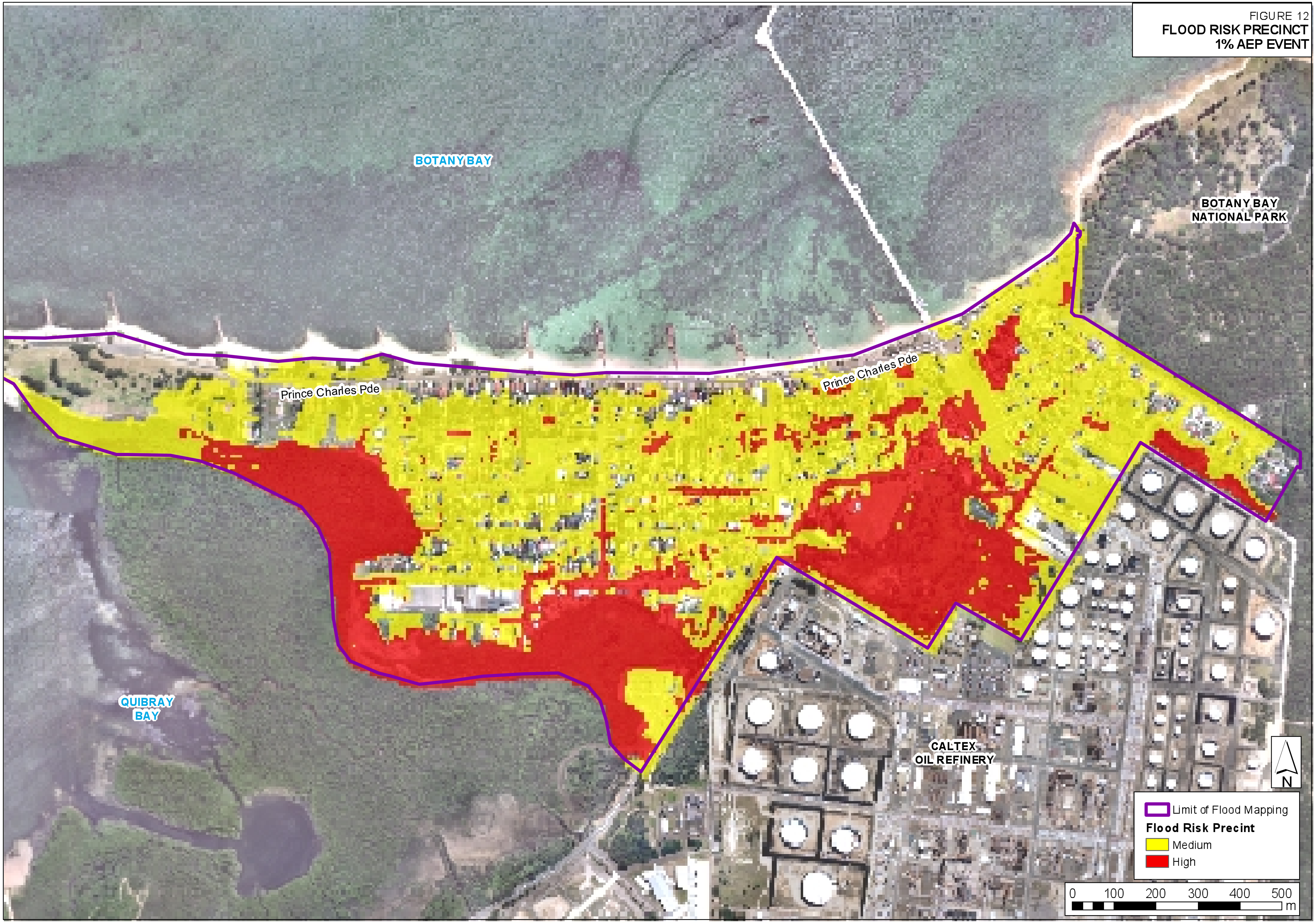
FIGURE 12
**FLOOD RISK PRECINCT**
**1% AEP EVENT**

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