

# FLASH FLOOD WARNING SYSTEM FOR SYDNEY'S NORTHERN BEACHES

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## Abstract

The Northern Beaches Flood Warning and Information Network program is a joint partnership venture between Pittwater, Warringah and Manly Councils with guidance from Office of Environment and Heritage (OEH) and Bureau of Meteorology (BoM). This regional approach has been utilised in order to combine resources such as funding and utilise the unique topography of the entire Northern Beaches for the strategic locations of gauges. Department of Public Works Manly Hydraulics Laboratory (MHL) has been engaged to undertake this program.

The aim of the program is to develop a basic flash flood warning system for the community, by strategically installing rainfall, water level and flow gauges. This has come about through the recommendations in Floodplain Risk Management Plans developed for various Northern Beaches catchments, all stating a flood warning system is a suitable method of managing the flood risk to residents.

Across the Northern Beaches there are currently 16 rainfall and 8 water level gauges. Over the next 5 years the current gauges will be upgraded and an additional 7 rainfall, 3 water level and 5 flow gauges will be installed.

A public webpage has been designed to provide the community with the real time gauged information, to help inform them on where flooding may be occurring. All data from the rainfall gauges will be uploaded to the webpage every 2 minutes and all water level gauges every 15 minutes. The data will be supplied to BoM to support their Severe Weather and Flash Flood warnings.

No flood warning system can continue to operate effectively or be improved without ongoing maintenance, evaluation and upgrading. This project attempts to install the necessary infrastructure in order to build upon in future years. The periodic reviews ensure that the lessons learnt from the experience of past flooding is not lost.

This paper will draw upon the reasons why this project was undertaken, the community engagement and the long term aims for the flash flooding warning system on the Northern Beaches.

## **Introduction**

Pittwater Council in partnership with Warringah and Manly Councils (The Councils) are implementing a basic flood warning system through the strategic location of a series of rainfall, water level and flow gauges.

The Northern Beaches<sup>1</sup> typically experience flooding from creeks, lagoons, overland flow paths, the open coast and Pittwater Estuary and Sydney Harbour. These sources of flooding generally result in flooding to properties within a short timeframe.

For flash flooding catchments in urban areas, there are limited flood mitigation measures that can be implemented to reduce the risk. It appears the most effective management options in order to reduce the risk to life, as specified in existing Floodplain Risk Management Plans are development controls, education and flood warning.

In order to successfully implement a robust flood warning system, a regional approach was needed due to the small catchments and the topographic nature of the Northern Beaches. In addition, the financial and staff resourcing benefits from existing collaborative arrangements for the management of adjoining floodplains was expanded to provide for a larger scope of works to be undertaken.

This webpage will advise the community of real time rainfall and the likelihood of rainfall that will cause flood issues for the Northern Beaches. It is acknowledged it is a basic system, but the community are more understand this format. It is anticipated that the webpage will provide a portal for residents and business owners to regularly check the weather, so that in times of severe weather residents are already familiar with the web site and can easily be informed on where to find information on where flooding may be occurring.

### ***Flood risk on the Northern Beaches***

To date the majority of the Northern Beaches has been studied to predict flood behaviour. The first flood studies were undertaken in 1990 and several catchments are now in the process of being updated.

The updated flood studies have shown the dominant flood risk to the Northern Beaches is flash flooding. Flash flooding is defined as flooding within six hours from the onset of rain (SES, 2008). This is generally flooding from creeks and overland flow paths. However, flooding from lagoons and the tide would also fit into this definition.

Flood Studies undertaken to date have predicted the critical duration for the 1% AEP (100 year ARI) for creeks and overland flow paths is generally two hours with a time to peak of approximately one to four hours. However, lagoon flooding typically has a critical duration of nine to twelve hours and a typical time to peak of approximately six hours (BMT WBM, 2013a & BMT WBM, 2013b).

The Northern Beaches has experienced large flood events in the past, including April 1998 (5% AEP) and March 2003. Although, numerous smaller flood events have also

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<sup>1</sup> The Northern Beaches area is bounded by North Head and Manly to the south, Middle Harbour to the west and Ku-ring-gai Chase National Park and Palm Beach to the north, with the Pacific Ocean to the east.

occurred, such as Narrabeen and Manly Lagoons in March 2011 (50% AEP), Avalon in 2008 (20% AEP) and Manly in 2010.

Flood Studies undertaken to date have shown that a total of approximately 7675 properties are at risk from flash flooding on the Northern Beaches in a Probable Maximum Flood (PMF). A map showing the current predicted PMF extents for the Northern Beaches is provided in Figure 1.

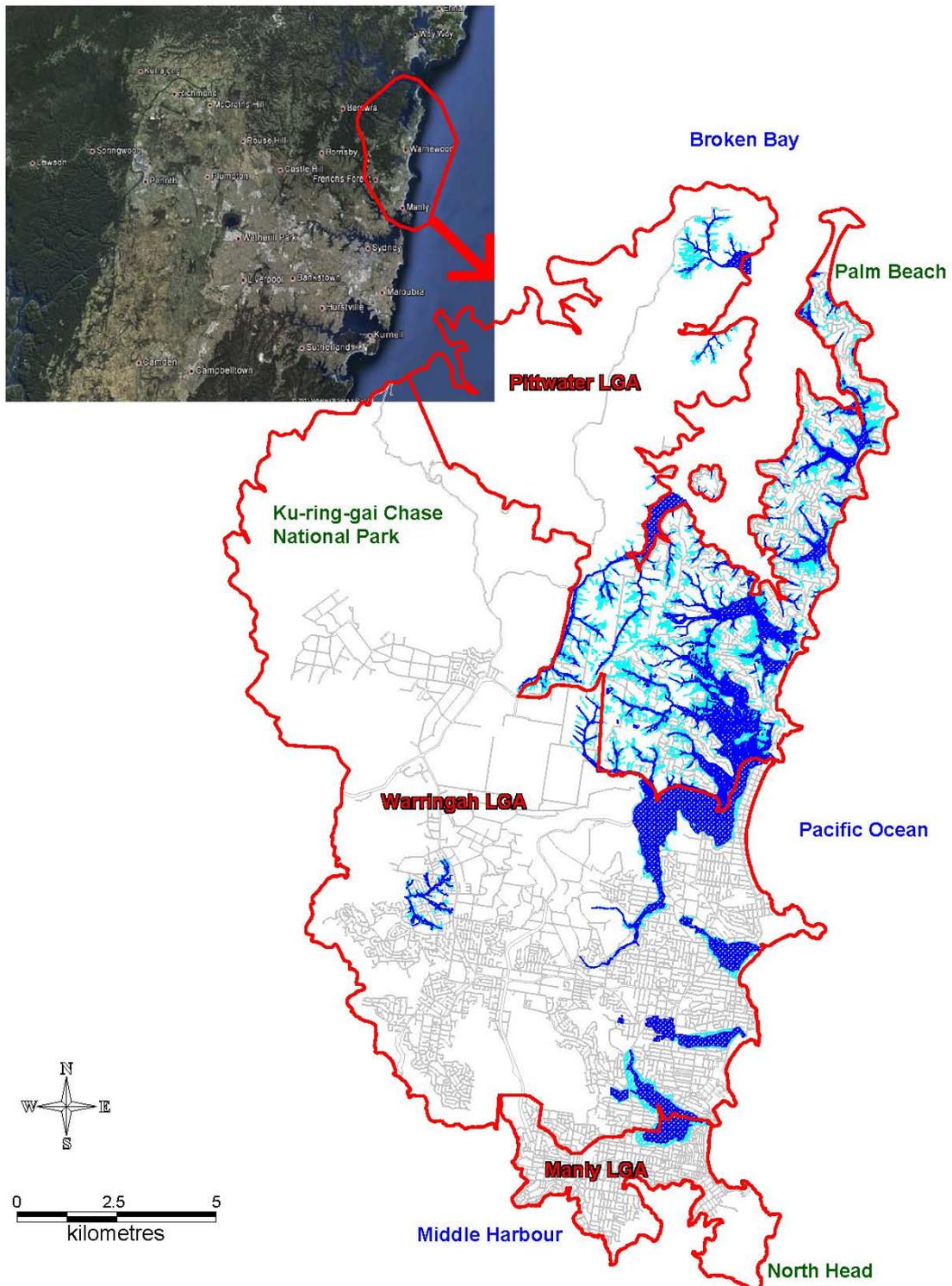


Figure 1: Map of PMF for Northern Beaches

## ***Floodplain Risk Management Plans***

Floodplain Risk Management Studies and Plans have been completed for the majority of catchments on the Northern Beaches, following the adoption of their respective Flood Studies. To date eight Floodplain Risk Management Plans have been completed and adopted by Councils on Sydney's Northern Beaches. These Plans have been completed according to the requirements of the Floodplain Development Manual with technical and financial assistance of the Floodplain Management Program, administered by OEH.

Floodplain Risk Management Plans have specified suitable flood, property and response modification options. However, the majority of catchments on the Northern Beaches are urban catchments with little or no space to construct flood modification measures. Any options listed within the Plans are generally medium priority for implementation due to high cost for construction.

Property specific management options such as developments controls and flood policies are already in place in each LGA. Other options such as voluntary purchase and voluntary house raising are generally not viable options on Sydney's Northern Beaches due to the high property market values.

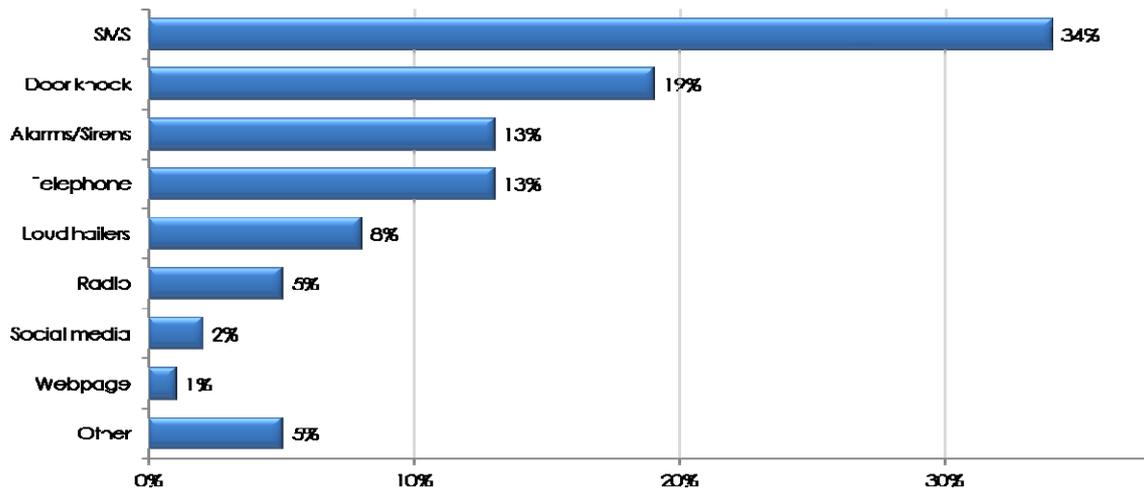
Therefore the only viable and cost effective management options appear to be response modification options. All Plans completed have stated that flood education and implementation of a flood warning system is considered a high priority. Although, the cost is significant as both options are known to have long term implications for ongoing impact and maintenance.

Each Council currently considers flood risk within their planning instruments and a regional approach to flood education has also been set up. As a result, a flood warning system for flash flooding was determined to be the next suitable method to continue in the management of flood risk.

## ***Community understanding of flood risk***

In May 2012, a community survey was undertaken by The Councils and NSW State Emergency Service (SES) to determine the level of understanding and awareness of flood preparedness and response to flooding and coastal erosion on the Northern Beaches.

The survey found that the Northern Beaches community has a very low level of concern for flooding and a moderately low level of concern for coastal erosion (Micromex, 2012). As shown in Figure 2, the survey also highlighted that during an emergency, residents preferred specific warning messages disseminated directly to them, *i.e.* through SMS messages and door knocks by the SES.



**Figure 2: Results from Community Survey question “What would be the best method for authorities to advise you of an imminent or occurring flood, severe storm or coastal erosion event”**

This survey has resulted in The Councils and the SES undertaking a regional approach in developing the Northern Beaches Flood and Coastal Storms Education Strategy (NSW SES, Manly, Warringah and Pittwater Councils, 2012) to raise the level of awareness and preparedness for flooding.

## Current Network

### *Lagoonwatch*

Since the early 1990s, eight water level and ten rainfall gauges owned and operated by Manly Hydraulics Laboratory (MHL) within the Northern Beaches have been leased to Warringah Council under a contract known as the “Lagoonwatch” system. The Lagoonwatch system was primarily used for lagoon entrance management (including having predictive capacities for lagoon level responses to rainfall) and provision of rainfall data for calibration in flood studies and stormwater infrastructure design.

The Lagoonwatch system has been administered under an annual contract by Warringah Council with MHL, with financial assistance also provided by Manly and Pittwater Councils.

These gauges were installed approximately 20 years ago and the Lagoonwatch contract covered the maintenance of the gauges and the provision of gauged data through a client based webpage.

The client based webpage has provided water level and rainfall data in real time format, *i.e.* water level data every six hours and rainfall data every three - four hours. The data format meant that issues arose with accessing this data and applying it to the flash flood response of the catchments.

The water level data was used mainly for flood mitigation decisions, *i.e.* the timing of mechanical openings of lagoons in order to prevent low lying properties from inundation. However, the delay in automatically receiving up to date information resulted in additional complications for Council staff. Historically a function to telephone each water level gauge to obtain latest readings was available, although this was removed when the gauge was upgraded to Internet Provided (IP) telemetry.

Whilst the Lagoonwatch contract met the basic needs of The Councils, there was no capacity for extending the network or to provide the community with access to the data, as a basis of a flood warning system.

Some of the older gauges were in need of upgrading or relocating whilst other gauges had been de-commissioned over time and new gauges installed in response to specific flood studies. The Councils also did not have an accurate record of where each gauge was or what type of gauge and telemetry system was used, which resulted in limitations when trying to apply the data.

By commencing a new contract the decommissioned gauges could be reinstalled and the additional gauges included in the same network. The physical gauges are still owned by MHL and BoM but leased to The Councils under this contract.

## **Flood Warning System**

The aims of the Northern Beaches Flood Warning network are to expand and improve the functionality of the existing Lagoonwatch system and provide:

- a sustainable regional approach to upgrading and installing rain, water level and flow gauges
- a basis for a flood warning system to the community
- The Councils with real time information on which to make flood management decisions (e.g. lagoon entrance management)
- collated information via an interactive webpage to the public and The Councils
- a long term (50 years) record of rain and flood behaviour across the Northern Beaches for use in flood studies and stormwater management
- a basis for a warning system of potential coastal erosion.

To meet the project aims, Pittwater Council entered into a partnership with Warringah and Manly Councils to undertake a contract with Department of Public Works Manly Hydraulics Laboratory (MHL). The contract is valid for five financial years from July 2012 until June 2017.

### ***Regional approach***

This regional approach has been utilised in order to combine resources such as funding and utilise the topography of the Northern Beaches for the strategic locations of gauges.

For the purposes of this project, the administration area is to be considered as an entire entity, divided only by catchments. The regional approach is to ensure each catchment is best represented in relation to the gauged network, as opposed to LGA boundaries as flood management is considered on a catchment basis. The political boundaries of the LGAs or wards do not influence the location of the gauges.

Each Council is committed to the project under a Project Agreement, which also specifies arrangements for each Council to in turn manage subsequent contracts. Fundamentally, the costs are divided between each Council according to the size of its LGA. Financial assistance over three years under the NSW Government Floodplain Management Program has also been made available for the installation of additional gauges and the webpage.

## ***Rainfall, water level and flow gauges network***

The basis of the flood warning system is a series of rainfall, water level and flow gauges with the data provided via an interactive webpage and series of trigger levels and alarms for relevant decision makers.

A Masterplan was developed to specify the program of works and order of priority for implementation of each gauge.

### *Masterplan*

The Masterplan provides a five year plan for the installation of new gauges. The plan specifies the final number, type and suitable locations of gauges to be implemented over the five years, whilst ensuring long term sustainability (*i.e.* longevity over 50 years).

The Masterplan was guided by “hotspot” areas or those catchments where detailed flood studies are shortly commencing. There are several areas on the Northern Beaches that are known to be “hotspot” areas or areas known to be of high risk to the community. These catchments were required to have a gauge that could benefit from flood warning.

The Masterplan also considered any land release areas or suburbs identified for development as these have the potential to change the longevity and reliability of the long term data record from hydrological changes in the catchments.

### *Rain gauges*

The location of the rain gauges was determined to ensure even coverage across the Northern Beaches with respect to the path of incoming flood producing storms. The rain gauges will form the basis of the flood warning system by providing real time information on actual rainfall which coupled with specific trigger levels will provide The Councils, SES, Roads and Maritime Services (RMS) and the community with an indication of where inundation is likely to be experienced.

Rain gauges provide a continuous record of rainfall, allowing event duration and rainfall intensity to be captured at a high resolution. Rain gauges should be located in such a way that the rainfall information captured best represents the spatial variability of the rain on the catchment as well as representing the most significant impact on flooding.

Figure 3 shows the location of existing and proposed rain gauges. The area to the south west of the region was also included in the network, as this is the prevailing direction of flood producing storms and could provide additional time for flood warning. As shown in Figure 3, the rain gauge at Spit Bridge was recommissioned as the most south westerly rain gauge.



**Figure 3: Location of Existing and Proposed Rain Gauges (MHL, 2013)**

The rain gauges operate on the tipping bucket principle. A receiver of 200mm diameter collects the rainfall, which is strained by a metal gauze before being passed through a siphon to a two compartment bucket mounted in unstable equilibrium. Tips of the metal bucket occur with each pre-determined volume of precipitation collected, this is specified as 0.5mm for all Northern Beaches gauges. A reed switch detects these events and produces a momentary contact closure signal for logging on a datalogger, which records each event as a time stamp (usually to 1-second resolution). An example of this type of gauge is shown in Figure 4.



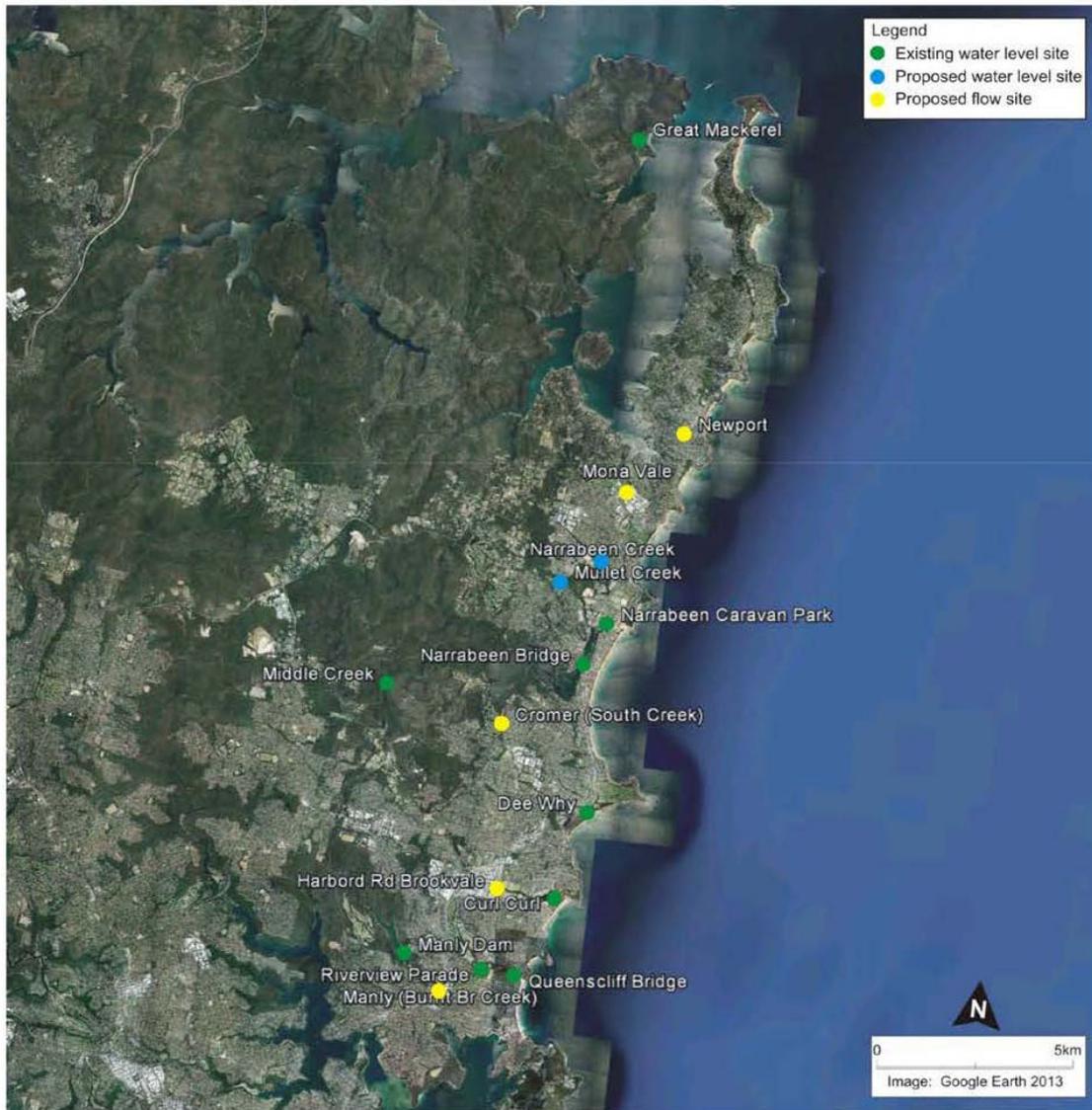
**Figure 4: Rain Gauge at Great Mackerel Beach**

BoM has three rain gauges on the Northern Beaches, as shown on Figure 3. Some rain gauges are selected to be compatible with BoM telemetry systems to enable long term sustainability and provide data as a back up in the event of failure of the Northern Beaches network.

Some of the existing BoM and Council rain gauges are within the same catchments. In order to ensure best coverage of rain gauges and best available long term data set is maintained, BoM are moving two of the daily read gauges to different locations within the same catchment to connect into the Northern Beaches Flood Warning network. As shown in Figure 3, these are Mona Vale and Avalon.

#### *Water level gauges*

The water level gauges are currently primarily used for flood mitigation decisions such as mechanical openings of the four lagoons on the Northern Beaches. In regards to flood warning, the strategic placing of several water level gauges on tributary creeks will provide warning to downstream areas at risk.



**Figure 5: Existing and Proposed Locations of Water Level and Flow Gauges (MHL, 2013)**

The current water level gauges installed across the Northern Beaches are using three different systems of data capture:

- Gas purge pressure system: the water level is determined by a pressurised constant flow of nitrogen gas through a line to a fixed point in the water column known as the orifice. The pressure in the line builds up to the same pressure as the water at that depth, this pressure is measured by the pressure sensor and converted into a water level by the data logger. The system relies on the principle that water depth is proportional to pressure
- Solid state Floatwell: the water level is sensed by a float connected to a shaft encoder.
- Submersible pressure transducer: the water level is determined by a vented pressure sensor and converted into a water level by the data logger.
- Ultrasonic/radar sensors: pulses are transmitted from the transducer towards the water and are reflected by the water back to the sensor. The elapsed time from emission to reception of the signals is dependent on the distance and hence the water level can be determined.



**Figure 6: Water Level Gauge (submersible pressure transducer) at Great Mackerel Beach**

The logging systems consist of Campbell Scientific data loggers which record water levels every 15 minutes.

#### *Telemetry*

Data from rain gauges can be communicated using a range of telemetry systems: radio, telephone, mobile phone, internet protocol (IP) and satellite systems. While IP telemetry can provide clients access to time series data in near-real time, it is reliant upon the NextG network which, may be affected by power and base station outages. The Northern Beaches network relies on the IP telemetry system with additional power sources, such as solar and battery to reduce the potential implications of a failure in the NextG network. The incoming raw data will be available to external users to view via the webpage every two minutes.

Water level data is transferred to the NSW Data Collection Warehouse, Data Centre 1 at Ultimo and to MHL's data server using internet protocol (IP), landline telephone, cellular networks and / or Event-reporting Radio Telemetry System (ERTS). The incoming raw data is then immediately available to external users to view via the webpage every 15 minutes.

Technology provides many opportunities to automate the detection, prediction and warning dissemination processes for flood warning. This is of particular advantage for local and broader scale flash flooding across urban and other heavily populated areas. One example used by BoM is the Event-reporting Radio Telemetry System (ERTS). ERTS uses VHF radio to transmit event data via a system of BoM operated and maintained repeaters, base stations and data collectors. ERTS systems have been successfully implemented in many small catchments throughout Australia, especially in circumstances where warning time is short. The data from six rain gauges within the Northern Beaches network will have dual telemetry systems to connect into BoM systems and feed into their Severe Weather and Flash Flood warnings.

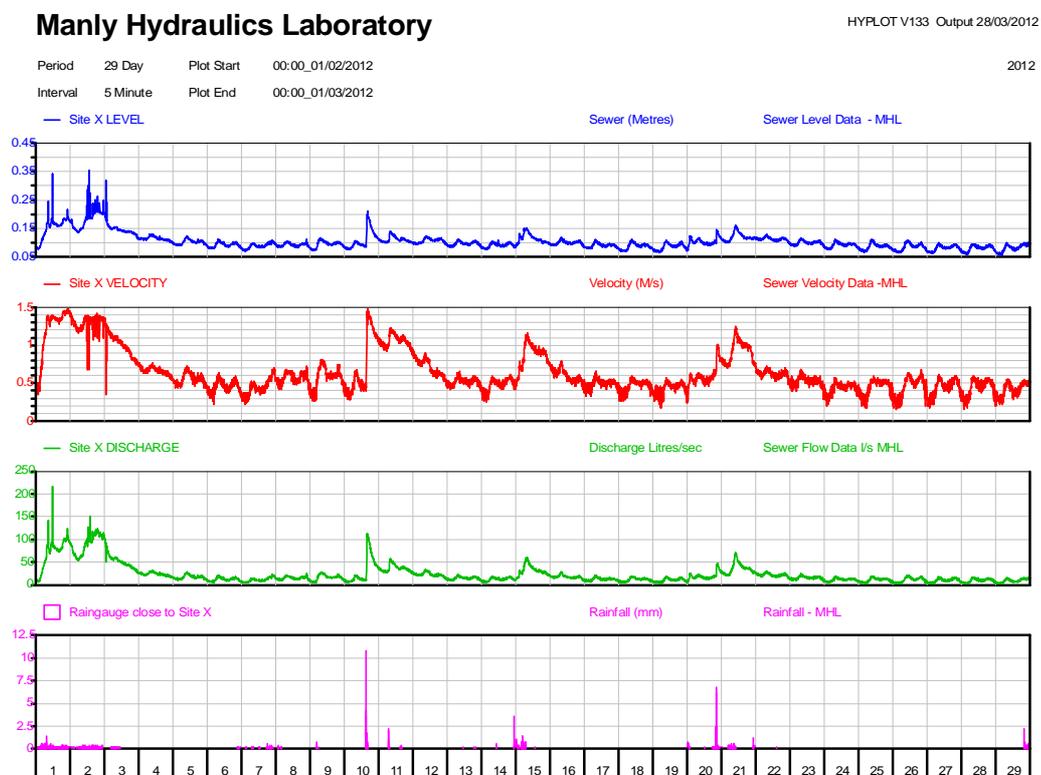
#### *Flow gauges*

It is proposed to install five flow gauges across various catchments within the Northern Beaches, as shown in Figure 3. It is anticipated that the flow gauges are used only for calibration of flood models and stormwater designs.

The Acoustic Doppler Current Profiler (ADCP) is an electronic instrument used to measure water velocities in two and three dimensions. The instrument transmits acoustic signals into the water column. When the frequency of the transmitted signals is compared with the frequency of backscatter signals reflected off particles in the water, the velocity of the particles can be calculated. Sites proposed for flow gauges were selected to ensure they are compatible with the operation of an ADCP.

The ultrasonic level and velocity sensor(s) will be installed at each designated location. The sensor measures water level using a capacitive pressure diaphragm. The range of the velocity sensor is  $\pm 0.025$  m/s to  $\pm 18.0$  m/s with an accuracy of 1% to 3 m/s. A multi-channel data logger will be also used at each site to log the water level and velocity data at five minute intervals and transmit the logged raw data to MHL.

The gauged data from the flow gauges will be available to The Councils through a secure webpage. Figure 7 shows an example of the outputs from a flow gauge in comparison to rainfall and water level gauges.



**Figure 7: Example of a Summary Plot Showing Relationship between Level, Flow, Discharge and Rainfall**

### Maintenance

All gauges need maintenance to ensure they operate correctly, provide accurate data and reduce the likelihood of failure during a flood event. Regular maintenance of gauges is vital to ensure high quality data is captured. Periodic reviews and a maintenance routine are necessary to guarantee that instruments are functioning reliability as expected. This is particularly important during major flood events when access to each gauge for maintenance will be difficult.

The cost of maintaining gauges is borne solely by The Councils, therefore the more gauges that are installed, the higher the ongoing cost to The Councils to maintain. Consequently, efficient, effective and strategic locations of gauges are very important.

Details of maintenance undertaken on the gauges will be provided in an Annual Report. This annual report provides The Councils with a record of any changes to the components of the gauges and details of any gaps or errors in the data that may have arisen.

### ***Alarms and trigger levels***

The alarms and trigger levels on selected gauges are the flood warning component of the system and provide details to relevant decision makers, *i.e.* The Councils, SES and RMS. For example, once a trigger level has been reached an SMS or equivalent is sent to relevant personnel. The trigger levels are set by The Councils and represent specific water levels and amounts of rainfall within a specific timeframe.

Currently there will be no alarms on the flow gauges and this data will be used for calibration of flood studies, as there are concerns that data collected from flow gauges maybe confusing for the community to understand. As shown in Figure 7, the data collected also includes water level, therefore it was agreed that there is limited benefit in providing additional flow data directly to the community.

### ***Rainfall alarms***

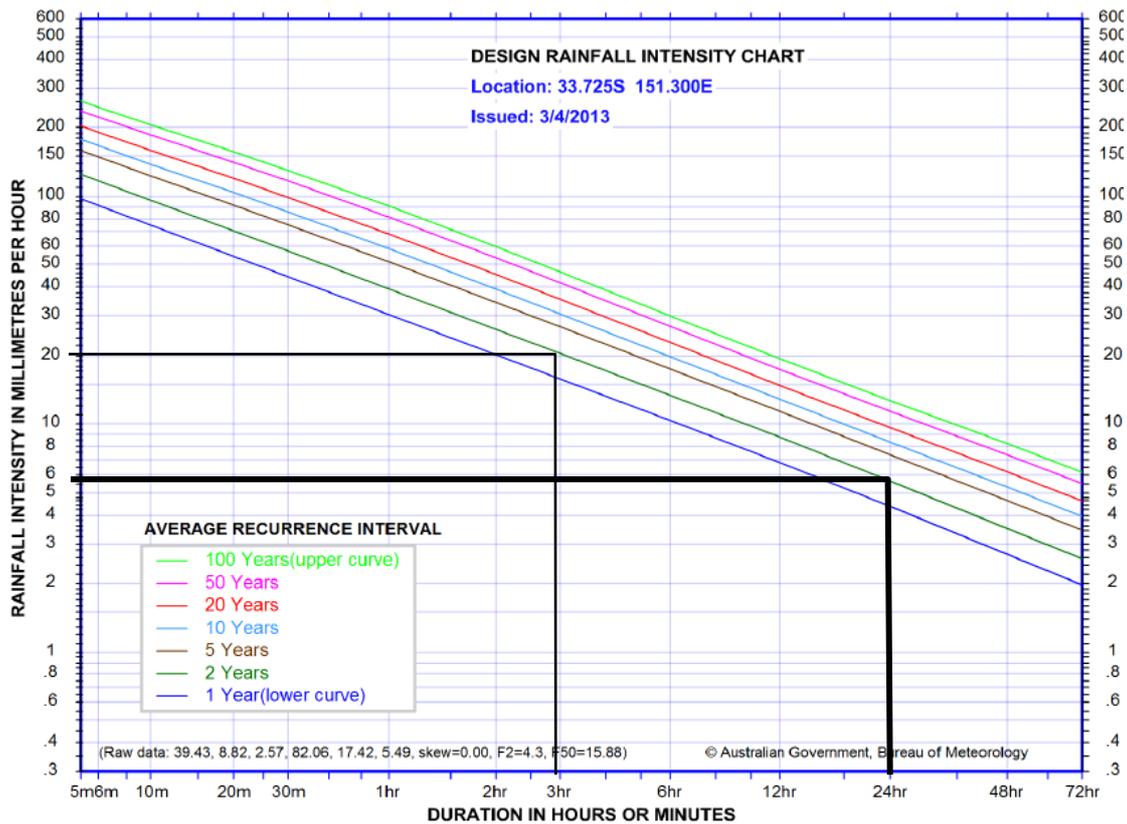
Through the upgrade in the rain gauge telemetry, alarms are able to be provided based on rainfall amounts. Six rain gauges have been chosen for alarms, namely Great Mackerel Beach, Narrabeen Creek, Forestville, North Curl Curl, Manly CBD and Spit Bridge. These gauges were chosen because they represent the likely incoming paths of storms that could produce flooding.

The trigger levels for the rainfall gauges are based on historical storms and advice from the BoM on other catchments across Sydney. For example, the Cooks River uses 20mm in 30 minutes (1 year ARI rainfall intensity) and 50mm in 1 hour (10 year ARI rainfall intensity). The majority of NSW uses trigger levels of between 15-30mm in 30 minutes.

Several Flood Studies completed for catchments in the Northern Beaches state that inundation and flooding issues are likely to arise when an event of between 50% AEP and 20% AEP (2-5 year ARI) occurs. This equates to total rainfall of:

- 70mm in 3 hours, generally occurring from summer thunderstorms and
- 150mm in 24 hours, generally occurring from east coast low systems.

The rainfall intensities are approximately 2 year ARI as shown on the Intensity Frequency Duration (IFD) curve for Narrabeen in Figure 8.



**Figure 8: IFD Curves for Narrabeen Lagoon (BoM, 2013)**

In comparison with other catchments, the total rainfall for the Northern Beaches is less than the NSW average. However, this is considered appropriate in terms of setting the levels too high or low to achieve the balance between raising the level of concern in the community and scare-mongering. It was determined that the following trigger levels would be used for setting alarms for the six rainfall gauges:

- 20mm in 1 hour
- 70mm in 3 hours
- 150mm in 24 hours.

The rainfall alarms are to be sent to trained personnel only, as there is some ambiguity around the amount of rainfall that will actually produce flooding, due to antecedent conditions.

#### *Water level alarms*

Alarms were provided on the water level gauges with the previous Lagoonwatch contract, primarily for use in mechanical openings of the lagoons. The Northern Beaches network will continue to provide these alarms, as well as additional alarms set at significantly high levels to provide a “heads up” on significant flooding. The water level alarms were determined based on:

- approximately the 50% AEP (2 year ARI) flood event level
- the level of which roads become inundated
- floor levels of low lying properties.

### *Distribution of alarms*

The alarms are provided by email or SMS to selected persons involved in flood making decisions, such as SES, The Councils and RMS. In order to distribute the SMS messages, MHL have purchased a bulk buy SMS system from Telstra. This system has a limited capacity and consequently, there is currently limited scope for extending this to providing SMS' to specific residents.

## **Community Involvement**

### ***Webpage***

The aim of the webpage is to provide actual rainfall and water level data in real real time to the community, SES and The Councils for reducing the risk to life and property from flooding.

An interactive webpage has been set up:

<http://new.mhl.nsw.gov.au/users/NBFloodWarning>

The webpage advises the community of the trigger levels for rainfall that could potentially flood problems. The trigger levels for rainfall are used in the flood warning system as the catchments typically experience flash flooding with little or no time to respond to trigger levels from water level gauges. The webpage provides up to date information on how much rainfall each gauge has received within three hours and 24 hours and 96 hours. Figure 9 shows the logo used on the webpage to advise the community of these rainfall amounts.



**Figure 9: Logo of rainfall amounts**

Rainfall data is uploaded to the internet every two minutes and water level gauges are displaying levels every 15 minutes. The timeframes used were selected taking into account the memory and electronic storage space needed for all the data as well as providing The Councils and SES with suitable data.

The webpage will not display any data from the flow gauges, due to the complicated nature of the outputs and technical knowledge required to understand and apply the information.

## **NSW SES**

The rainfall and water level alarms are sent to the NSW SES Region (Sydney Northern) and the Local Controllers (Manly and Pittwater-Warringah). In order to facilitate understanding of these alarms a “cheat sheet” has been developed to explain the implications of the trigger levels.

The NSW SES logos are also used on the homepage of the website in order to promote their role.

### ***Warning system for coastal erosion***

The webpage provides a basic warning system for coastal erosion. The homepage displays the current weather warnings provided directly from BoM. This includes warnings for damaging surf and dangerous surf, which provides a “heads up” for coastal erosion.

### ***Promoting the webpage***

The flood warning system is a user friendly and valuable resource for broadcasting to the community imminent flood conditions. Promoting this tool is essential to encourage the use from residents and business owners.

Conveying the message that the webpage is the primary place to obtain local flood warning data is essential to the success of the flood warning system. The Northern Beaches Flood and Coastal Storm Education Strategy complements the Northern Beaches Flood Warning Network by also providing actions to regularly promote the webpage.

The webpage will be regularly promoted by each Council and SES to increase the number of users. The following methods include:

- NSW SES Flash Flood Guide for Pittwater LGA (and shortly Manly LGA)
- Links on each Council webpage
- Regular social media updates by each Council to the webpage, especially during large rain events
- Council newsletters
- Presentations by NSW SES in schools
- Local newspaper, *i.e* Manly Daily
- Attendance by NSW SES at festivals and events
- Provision of information to local businesses through the Chamber of Commerce.

### **Future Directions**

It is acknowledged that a flood warning system for flash flooding on the Northern Beaches will be limited in its nature. However, The Councils' aim is to locate gauges in representative locations for use in a basic flood warning system. It is basic in its nature due to the limited distribution of messages to the community. During subsequent contracts, a more sophisticated flood warning system may be implemented as technology improves. It is important to convey that this system is basic and this

contract is primarily putting in place the infrastructure that will be needed for a more advanced system.

With the long term nature of these gauges, there is a big commitment needed by all parties involved. It is perceived that the location of the gauges implemented in the next five years will still be providing data in 50 years time.

The use of web-cameras for lagoon entrance management may also be considered. Currently, if an east coast low system is developing a camera can be set up to record the influence of the tide on the lagoon entrance. However, there are limitations with this, such as the lack of light during the night. When the technology becomes available, a camera permanently installed to physically view the berm height relative to water level at the lagoon entrances through the internet would aid in timely flood mitigation decisions and in providing more comprehensive warnings for coastal erosion.

To increase the community's awareness of flood risk areas, it is proposed the webpage will become an interactive social media style webpage that residents will be able to upload photos of "live" flooding as they experience it onto a map. This will advise other residents of actual inundated areas that should be avoided.

As shown in the community survey (Figure 2), residents would like to be advised of an imminent risk through the use of SMS'. The use of SMS' is used by other agencies during emergencies to advise residents of imminent danger and is considered effective in getting the message to impacted residents. In subsequent contracts, The Councils will be looking to implement a system where residents are able to opt into a SMS alarm system, advising of specific rainfall amounts and / or trigger levels from water level gauges within close proximity to their property. It is envisaged this would only be available for flood affected residents in order to limit the users to a manageable number.

## **Lessons Learnt**

It is acknowledged that the flash flood warning system for the Northern Beaches will have limited functionality. However, The Councils' aim is to locate gauges in representative locations for use in a basic system. During subsequent contracts, a more sophisticated flood warning system may be implemented as technology improves. It is important to convey that this system is basic and this contract is primarily putting in place the infrastructure that will be needed for a more advanced system.

With the long term nature of these gauges, there is a big commitment needed by all parties involved. It is perceived that the location of the gauges implemented in the next five years will still be providing data in 50 years time.

## **Take Home Messages**

1. Rainfall, water level and flow gauges are essential for providing long term data for calibration of flood models. They can, however, also be used for additional purposes such as flood warnings or for designing stormwater infrastructure systems. We all need to make sure we utilise these gauges to their full capability so we can realise the full benefit of their installation.

2. It is perceived that the gauges implemented in the next five years will still be providing data in 50 years time. With the long term nature of these gauges, there is a big commitment needed by all parties involved for the ongoing maintenance. If the whole region is involved in the process, it will share the load as well as spread the knowledge to SES local units.
3. Flash flood warning systems have to provide accurate real real time data. This is only now being made possible through advances in telemetry and webpage based data transfer. In order to provide the best available warning time, trigger levels for rainfall have been used, rather than water levels.
4. The effectiveness of the flash flood warning system is dependant on how the flood warning messages are provided to the community and their response to these messages. Therefore, the webpage needs to remain basic to ensure the message is clearly received and understood. It is hoped that ongoing education will successfully promote the webpage. But it is also likely that education timed with any future flood events may increase community receptiveness.

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