NSW URBAN LEVEES REVIEW PROJECT – IMPROVING OUR KNOWLEDGE AND MANAGEMENT OF FLOOD LEVEES FOR NSW COMMUNITIES

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Abstract

Urban flood levees can provide effective and significant reductions in property damage and allow communities to remain functioning during long-duration floods. But they can also be a source of uncertainty and controversy when managing flood response.

Significant flood events experienced in NSW in late 2011 and early 2012 highlighted the need for a centralised, accurate and comprehensive source of definitive technical information on levees across the state. This information is particularly important for emergency services and levee owners to base critical decisions on during the management of flood emergency response and also for long term infrastructure management.

To assist in improving the availability of technical information on levees the Ministry for Police and Emergency Services (MPES) engaged NSW Public Works to carry out a review of urban levees in public ownership to assist the NSW Government. In particular this is aimed at the Office of Environment and Heritage (OEH), NSW State Emergency Service (NSW SES) and Local Government. The first part of this review was to develop a comprehensive database of reliable information on levees protecting communities in NSW and establish guidelines for levee information requirements and for management of levees by levee owners.

The key outcomes and benefits sought from the project are to:
1. Improve emergency planning and response capabilities;
2. Have a comprehensive, accurate database of key information on all urban flood levees in NSW for use in flood planning and emergency response;
3. Undertake detailed assessments of “at-risk” levees;
4. Give the State a current appreciation of the risk exposure for flood levees; and
5. Develop a guideline on requirements for the management of levees

The project will also establish the data sets required for a future online information portal to manage and access accurate information including spatial data on levees.

Introduction

The flood events experienced from 22nd November 2011 to 30th April 2012 were significant in terms of flood height, water volume and geographic extent in many river systems in NSW. Many communities located in floodplains in NSW are protected by

levee banks and these are known to be in a range of conditions - from well engineered and well maintained structures to those of unknown quality, integrity and capability. While not a new issue, it became increasingly evident during these floods that there was a lack of comprehensive, accurate and definitive technical information on levees for emergency services on which to base critical decisions.

Levees in NSW are managed by their owners, which has led to a situation where there is no central coordinated source of data for levees which created a challenging decision making environment for emergency managers and owners, mainly Local Councils.

Perhaps the most evident and challenging consequence of poor data is in relation to decision making on evacuations of communities in an environment of high uncertainty.

To explore this and the broader impacts on levee management the paper will present a key decision making paradigm for emergency risk management and some non-negotiable elements or hard truths of the decision making for levees.

This paper will also present a summary of the 2012 NSW Urban Levees Review project methodology and outputs and conclude with insights to the future of the development of a levee management programme use cases for the information.

Playing chicken with levees

The decision making paradigm for emergency managers is a complicated and multi-faceted arena. The human, social and political aspects of risk based decisions are laced with emotion, diverging views and differing responsibility for community safety and liability brings a very high complexity to dealing with levees during an emergency. Yet in other ways emergency decisions can be simple if viewed the right way.

To unpack these issues for levees we will begin by introducing the decision making paradigm adopted by the NSW SES. Then we will look at these in relation to some inconvenient truths which in the end can potentially make dealing with levees more straightforward - leaving the key challenge then of effectively communicating and engaging about the decision making process and gaining community commitment to the actions required. It will be shown that if one does have to play chicken with levees it is always better to take calculated risks and not chances.

The emergency management and decision making paradigm

The paradigm, simply, is that the only credible strategy to deal with uncertainty is to plan and implement mitigation strategies until it is proven they are not required.

In other words, if the key strategy for community safety is evacuation and if there is uncertainty whether evacuation will be required, then you must plan for and implement that evacuation until it is proven credible that it is no longer required. The decision is therefore not whether evacuation should be commenced, although “when” is a valid question, but rather when evacuation can or should the evacuation be stopped.

This reversed perspective on evacuation decision making was adopted within the NSW SES around 2010 during the flood events. The paradigm is now part of an important discussion with Councils and communities during flood planning and flood events.

Unassailable truths

Within the frame of the decision paradigm there are important, essentially non-negotiable factors that when considered in combination make a complex situation simpler.

These are: known uncertainties, time, and levee trigger heights.

Known Uncertainties

Known uncertainties arise in any given flood as there is always uncertainty of the peak height and the timing of that peak. It is only in rarer, larger floods where uncertainty will conveniently be removed when the forecast flood is much greater than the decision points or key levee heights and evacuation will be an urgent priority.

For smaller floods, there will be uncertainty about when to commence an evacuation but when faced with the uncertainty of whether to evacuate, inevitably as time progresses there will simply be a point when there is only one credible course of action despite the uncertainty on the eventual outcome of a flood. As the time available to implement actions intersects with the time required to implement those actions before a potential consequence, there is thus certainty.

So paradoxically while uncertainty remains, due to the requirement of having time to prepare, commence and complete evacuations there is certainty of the planning and implementation that should be undertaken.

Time

There are two key times that emergency managers must consider:

1. the time it takes to warn and evacuate a community; and
2. how much time before a trigger is reached.

The evacuation of communities have significant mobilisation, warning and evacuation movement time components which together can often take 12 hours or more to complete even for many smaller communities.

Evacuations must be commenced well in advance of an expected trigger or threat level occurring. The time required for “safe” evacuation must be made available before this trigger is reached by enacting an early decision. When time runs out for the evacuation, the incident technically transitions to the “rescue phase” where people may be trapped requiring rescue or in the worst case becoming fatalities.

Levee Trigger heights

Triggers signify a time or flood level after which it is no longer “safe” for a community behind a levee:

- in the best case they represent the limit of effective flood operation;
- and in the worst case when levee overtopping commences or a breach is possible

In the NSW emergency management context the NSW SES manages a flood intelligence system which denotes triggers and other key heights in relation to flood levels measured at a key flood warning gauge in the area.

As a flood develops, if it is predicted or forecast that the river could reach or exceed key heights recorded in SES flood intelligence, particularly for evacuation, incident

planning and decisions should be undertaken that allows enough time to implement those actions before that height it reached.

To Cross or not to Cross the Chicken asks ?

Some may argue that the emergency decision paradigm above presents a simplified view of how to deal with uncertainty, risk and known or unknown triggers associated with levees.

Yet despite the complexities inherent in real life events when confronted with uncertainty, decision makers, sometimes reluctantly, generally only make the one decision….. to evacuate.

When faced by an assessment of whether there is evidence or certainty about a levees flood capacity, about emergency earth works that have been "pushed up" prior to the flood or about what will happen if the levee breaches, "gut feels" and assumption do not survive the test of emergency risk assessment and discharge of due diligence.

However the situation is far from perfect. Levee evacuations enacted because of the lack of certain reliable information lead to an unnecessarily high factor of safety. This in turn leads to lack of credibility over the decision from the communities' perspective. In some cases a cautionary approach will be evident in a community that has not experienced flooding for a long time, however if flooding happens again soon after or in locations where flooding is common the partnership with communities often breaks down and trust is eroded.

With the collective knowledge, even if empirical or heuristic, of Councils, emergency services and communities about many levees across the state it not unreasonable to say that binary triggers to evacuate an entire community behind a levee are not the only way to manage community safety. Implementation of emergency actions such as monitoring and surveillance, engineered emergency contingency works and staged evacuations based on risk assessments may all be applicable strategies during an incident. Correct implementation of these actions may mean that it is appropriate that some or all of a community may remain behind a levee even when its effective flood operating height is exceeded.

However without an authoritative assessment of these emergency actions undertaken pre-flood, generally speaking these are not credible options to develop "on the fly". The simple outcome is that without authoritative evidence of the assumed increase in the levees flood operating level assumed from emergency actions, that under the test of emergency risk management and probity the actions cannot replace the previously known trigger heights.

It was this requirement to have a formal and robust approach for levee assessment which heavily informed the development of the NSW Urban Levee Review and the issues above have formed key tenants in the development of the project methodology.

So in respect to the chicken it may not be merely a case of whether to cross or not – in other words to choose not to evacuate or; to evacuate to safety. It may be that crossing the road is appropriate but it will require good risk assessment and engineering data for an informed decision. The decision will involve consulting a Levee Owner's Manual, a Levee Summary Report, and the Levee Safety Annex of the local Government's Local Flood Emergency Sub Plan and the paper will now discuss these components of the NSW Urban Levee Review.

The NSW Urban Levees Review

The 2012 NSW Urban Levees Review builds on the 2010 NSW SES, NSW Levee Study for Emergency Management. The 2010 study, funded by through the Natural Disaster Mitigation Program, presented the results of a desktop review of existing studies and data pertaining to 59 significant urban levees in NSW.

While this 2010 study was an improvement in the completeness of data at that time, there was no formal process to keep it up to date and so it rapidly became "out of date" and voracity in the data uncertain.

So it remained evident during the 2012 floods that there was a lack of comprehensive, accurate and definitive technical information on which to base critical decisions. It was believed truly reliable and up to date information was available on only around 25 of then known 80+ levees in NSW and in fact the total number of non-private levees/levee systems has now been found to be in excess of 110.

Some of the necessary information existed, but it is scattered and uncoordinated. Some of the information held has been found not to be accurate and/or out of date. Local Councils who control the levees sometimes do not have staff familiar with the information (due to staff turnover etc.) or, sometimes, may not be aware of the information or where it is stored in the Council records system.

In the recovery period to the 2012 floods MPES initiated and funded a project to improve flood levee emergency response. A project Steering Committee comprising of the NSW Deputy Engineering Functional Area Co-ordinator (ESFAC), NSW Public Works, NSW SES and OEH prepared the project methodology and NSW Public Works executed the work.

This project aims to develop a database of reliable information on existing levees and establish standards for information requirements and for management of levees by levee owners.

The database developed will provide operational benefits primarily to the NSW SES, OEH and Local Councils. The database will be supplemented by reporting and summaries of key levee information and visual audit condition reports.

Project Approach and Phases

The project has been broken into three distinct phases which are now nearing completion in Stage 1 of the Urban Levee Review. The phases are:

1. Collect and review available levees information from all services and update the NSW SES flood database with a supporting NSW levee database.
2. Field surveys and engineering audits of levees to fill in data gaps and state survey documents.
3. Develop an Levee Owners Guideline and general policy for levee owner's manuals and maintenance.

Phase 1 includes four work items which are:

1A. Expansion of NSW Flood Database and data management;

NSW SES and OEH have been completing a NSW Flood Database project with funding assistance from MPES. The NSW Flood Database is an ESRI based geospatial database containing spatial, attribute and a-spatial report data on floods and levees. Levee data captured in Urban Levee Review project has been aligned with this data set to establish consistency and enable consistent data management and user tools. It will include a report template system, data standards, and checking/verification methods.

The database is required to store documents and access their data from a number of key sources:

- visual condition audit reporting on the levee and any recommendations for changing maintenance or upgrades.
- Operation and Maintenance Manual – for Council .
- forward works program for upgrade or major rectification works.
- agreed Effective Flood Operating Level
- NSW SES and Council Local Flood Emergency Sub Plan for evacuation and emergency response
- contingency plans for emergency actions and for protection of community services.

1B. Levee Master List Compilation

At the commencement of the project there was no complete list of all urban levees in NSW owned and managed by State and Local Government (privately owned and rural levees are not part of the database or this study).

NSW Public Works compiled a preliminary master list of Urban Levees in NSW from available NSW SES data, NSW Office of Water licensing information and NSW Public Works' audit information. The master list was then circulated to local Government and agency contacts for confirmation. A total of 112 levees/levee systems were identified.

1C. Levee Data Collection

Data for each levee was collected via desktop audit to compile available information from the NSW SES, other NSW levee studies (NSW SES 2010), OEH, NSW Office of Water, Councils, and Public Works staff. The regional District Engineering Services Functional Area Coordinators assisted in this task to retain the connection and input of key players at a local level.

A survey was sent to all known levee owners. The information returned in the survey formed the first population of the levee database and included:

Key data:

- flood gauge height, level (m AHD) and location

- design flood levels at the levee, with correlation between gauge height and levee heights and flood gradients
- survey of levee and levee crest levels (and relationship to gauge height).
- flood frequency and flood level relationships
- infrastructure protected by levee (population and critical infrastructure such as telephone exchange, electricity substation).

Other Data (where readily available) may include:

- other survey (e.g. town, critical infrastructure levels)
- Levee Operations and Maintenance Manuals
- work-as-executed documentation for the levees
- flood study reports
- Floodplain Risk Management Studies
- Floodplain Risk Management Plans
- levee design reports
- other engineering reports and audits.

1D. Presentation of Summary Information

A brief report summarising the key findings, including the methodology defined in the Levee Owners Guideline will be the final output of this data collection phase. The report includes a summary table that details the available information for each levee and would be the basis of a gap analysis and prioritising of funds expenditure in future projects.

Phase 2 – FIELD DATA CAPTURE

Phase 1 identified what additional information is required for each levee. A priority list was then agreed by the committee and from a risk assessment process, the gaps in information were filled using either:

- 2A. Field Survey Data Capture – survey levee crest heights for survey gaps
- 2B. Condition Assessment – Visual Audit Methodology for unknown levee condition
- Future stages - if necessary a detailed levee assessment for critical levee which would be flagged as part of future stages of the Urban Levee Review programme of works.

2A. Field Survey Data Capture

Data gathering involved survey and gathering spatial data on levees that have no, or only partially existing, survey information, or survey information for which its origin, accuracy, or reliability cannot be verified or outdated.

Levee crest level information was collected for priority levees/levee systems using conventional survey techniques.

2B. Condition Assessment – Visual Audits

Visual levee audits provide a means of gathering information and NSW Public Works have been, and is continuing to undertake these for particular clients, including OEH and individual Councils. The outcome of these audits is a Visual Audit Report which identifies and describes defects in the levee and gives an indication of the flood level for which each levee is likely to effectively operate. The Visual Audit methodology is discussed in more detail in the paper entitled "Developing a systematic approach to monitoring the condition of levees in NSW", FMA 2014, Duncan McLuckie, John Dixon, Fred Spain.

A visual engineering inspection and report, initially on priority levees will be completed. The priority levees were selected on range of risk factors ranging from existing engineering information, those with known deficiencies, those with no inspection within the last say 5 years, and those with a high failure consequence and complex or contentious emergency management decision making requirements.

A longer term audit program will be established to keep currency in information and inform upgrade and maintenance work undertaken by Councils and supported by NSW Government.

Some of the key components of an audit report are as follows:

- description of the levee
- details of previous levee audit
- limitations of the audit
- review the available documentation
- outline issues with the levee
- identify and report each issue or risk to the levee in the report
- include photographs of the levee to aid comparison over time
- rank issues in relation to their risk
- provide advice in relation to the types of rectification works necessary
- provide an overview of overall levee condition
- outline any additional investigations recommended.

An electronic copy of the audit report would be issued to each Council as well as being integrated into the NSW Flood Database system.

As part of this levee review project, we also propose to include identification of evidence of regular operation and maintenance activities.

Deficiencies in these documents will be highlighted and recommendations made in relation to improvement against standard documents outlined a Levee Owner's Manual.

2C. Levee Summary Report Covering each Levee in NSW

A report summarising the key information on each levee will be produced. It is intended that all key information and assessment will be stored in the NSW Flood Database. Standard reports will be produced in the first stage of the project from the database. But in later stages this will progress to more complex approaches to data querying, information overlays and assessments of data for risk assessment. These will be developed during further enhancements to user tools and the database.

Phase 3 LEVEE OWNERS GUIDELINE

There is currently little specific guidance for owners of levees to assist in managing their assets. To address this, a key output of the project will be the development of a Levee Owners Guideline. The guideline has been specifically written for NSW levees taking account of the current levee management framework and draws on international practice from the US Army Corps of Engineers Manuals (*Levee Owner's Manual for Non-Federal Flood Control Works, 2006; Flood Fight Handbook – Preparing for a Flood, 2009; Design and Construction of Levees, 2000*) and the draft International Levee Handbook (in preparation). It will provide guidance on the basics of what needs to be undertaken to ensure the ongoing successful operation of a levee during a flood. This will maximise the benefits provided by a levee in protecting the community from the impact of flooding and assist in reducing the State's risk from flooding.

The guideline covers the following:

- an overview of levees in NSW
- owner's responsibilities relating to due diligence requirements e.g. Operations and Maintenance (O&M) activities and communications
- basic principles covering types of levees in NSW, basic design principles, basis for establishing an "effective flood operating level and gauge levels and flood slopes
- Levee Owners Manual preparation guidance
- operations and maintenance requirements covering documentation and records management, inspections required, maintenance program
- Communication Plan to share knowledge to make sure everyone knows when significant changes to the levee occur
- Guidelines for emergency contingency works

Effective Flood Operating Level

One of the key outcomes of the Urban Levees Review aimed at improving emergency response is to develop reliable data on the flood level which levees can be expected to safely operate to during an event – the "effective flood operating level."

One factor that became evident during the review is that there is much confusion in the industry around the use of design flood levels, imminent failure levels, safe operating levels etc. In addition a set of accurate and up to date data does not exist for many levees and data that is currently being used for decision making may be well out of date or simply not relevant.

A new term, “Interim Effective Flood Operating Level” is proposed to describe a flood operating level (measured at a reference point such as a flood gauge) estimated using an empirical methodology developed for this project. It is defined as:

“The flood level for which the levee can be expected to effectively operate with reasonable certainty that failure of the levee will not unexpectedly occur during a flood event”.

The Interim Effective Flood Operating Level is an interim measure to give a preliminary level to use where no other reliable information exists, pending a more rigorous engineering analysis. It is for use only for the purpose of emergency response.

This Interim Effective Flood Operating Level is not a level of ‘guaranteed safe protection’ as it will be derived on an assessment of an existing levee invariably based on limited data and there will always be some uncertainty.

The levee may, in fact, successfully provide protection against a higher flood than derived using this method but with lower levels of confidence that it will not fail.

In summary, the empirical methodology is based on a levee’s history and condition, whether it has been recently tested by a flood and found satisfactory, whether it can be strengthened and repaired during a flood if problems develop.

The methodology to determine the interim level involves broadly the following steps (refer to the Draft Levee Guidelines for details):

(a) Identify the level of the flood of record (at the relevant river gauge) which the levee is known to have satisfactorily performed in its current configuration and condition.
(b) Obtain a recent centreline survey of the full length of the levee crest
(c) Determine a flood slope or flood gradient (for the above flood of record) to derive actual flood levels for the full length of the levee
(d) Determine a required minimum flood event freeboard for wave action and local surge effects
(e) Obtain a recent visual audit of the levee in general accordance with the Visual Audit Methodology to assess the condition of the levee
(f) Undertake a review of past performance in floods, previous investigation reports and anecdotal evidence from a range of sources. The review will also assess the impacts of related issues which could affect the reliability of the levee e.g. Old designs, non engineered ‘top ups’
(g) Based on the findings of the visual audits and review, classify the levee on a scale of 1 to 3 according to an overall assessment of condition and consequent overall ability to reliably retain flood water
(h) Calculate “Interim Effective Flood Operating Level” by deducting from the minimum crest level, the flood event freeboard and a capacity reduction factor applicable to that classification, but adjusted by the level of flood of record experienced.

For older levees in poor condition and not being maintained, this may give a level well below that currently in use. This reflects the uncertainty of its capacity to reliably protect against floods. There are conditions attached to the methodology’s use and it will not be applicable for all levees.

Note that the methodology is intended to only be applied by suitably qualified and experienced levee engineers. It is also expected that the actual Effective Flood

Operating Level would be confirmed by more rigorous engineering investigation and review as soon as practicable, and within no more than 5 years.

FUTURE PHASES

Trial Levee Owner's Manual

Levees will be selected in discussion with Council, NSW SES and OEH to have trial owner's manual developed. The trial manual will compile findings of Stage 1 of the Urban Levees project and develop a manual in collaboration with Council. The Levee Owners Guideline will be also be revised based on feedback from the process.

Workshop on levee ownership

A short course will be developed based on the visual levee audit project with the aim of providing training for Council, consultants, Public Works and other personnel. Training capability for these personnel will support the development of a long term visual audit programme which will keep the data collected in the Urban Levee Review project up to date.

As a part of the short course development, piloting and workshop sessions will be held at the Floodplain Management Association Conference in May 2014.

Levee database development and end user scoping

Further development of the levee database will be undertaken to expand the information contained in the data store. The work will facilitate effective capture, maintenance and use of all available data. Work completed to support this includes:

- expansion of the database schema to incorporate spatial and a-spatial from all reviews and reporting produced by the project; and
- harmonising the available levee data with the NSW Flood Database currently under development by NSW SES and OEH.

A user requirements definition process will also be undertaken to develop use cases and determine options for user platform to leverage the data in business as usual planning. Key examples of user cases include:

- workflows and portals for the update and maintenance of levee data by all stakeholders
- workflows for emergency planners that use data layers and more complex data analytics to determine risk assessment information for population at risk, evacuation planning, emergency sector development
- knowledge management and data discovery tools that bring all available documents and data together for a levee

Levee Safety Annex of Local Flood Emergency Plans

As discussed previously it is important that assessment of emergency actions is done prior to events so that decisions are based on reliable data. Also in order for the work

produced by the Urban Levee Review project to inform revised emergency management triggers, it must be integrated into the emergency planning process undertaken by NSW SES. To achieve this NSW SES will develop a template Levee Safety Annex for inclusion in Local Flood Emergency Sub Plans (LFP). The Annex will combine data from the levee project, assessment of that data in an emergency planning context and the outcomes of consultation with local Council on the adopted emergency planning strategies for that levee.

In a later stage of the Urban Levees project, levee safety annexes for key high risk levees will be developed in consultation with Council and communities during workshops. All other annexes will developed over time during the 5 yearly review cycle of Local Flood Plans.

Priority detailed assessments

Through the course of the project gaps will be identified across the range of levees. For critical levees, detailed engineering and risk studies will be planned in future stages of the project. It must be remembered that gaps in information during emergency decision making can be difficult to deal with and this will be the case of any levee regardless of the overall level of risk it poses. Therefore based on advice from the NSW SES, levees targeted in this future work will not only include the higher risk levees, but also lower risk levees where large gaps are evident or where there are known issues in being able to make effective and sustainable emergency management decisions.

The purpose of the detailed studies would be to accurately verify: levee condition, flood risk behind the levee, the effective flood operating level, relationship to flood warning gauges for NSW SES flood intelligence, and provide recommendations on emergency engineering works.

The extent of work will depend on the individual levee but could include geotechnical investigations, detailed levee gradient assessments, crest level surveys, flood studies or levee breach modelling.

Conclusion

Flood levees are an important flood mitigation measure that allow communities to manage and recover from the impacts of flooding. However to be an effective levee it requires that it is not just constructed, documented at a moment in time and left to weather and degrade. An effective levee for which Council, emergency managers and the community can have confidence in requires good maintenance, regular assessment and a collaborative and up to date plan on what actions and strategies need to be put in place during flood events. Without these important elements, levees have the very real potential to create controversy, division and distrust of authorities, ultimately jeopardising the success of future decision making when that inevitable large flood seriously threatens the operating level that a levee provides.

The NSW Urban Levees Review is a significant establishment in the development of a levee management programme. The data set that the project will create will form the basis of a comprehensive data store on levees and will enable significant evolution of the systems and tools used to manage levees. With enhancements and supporting mechanisms developed over coming years to assist levee owners to assess, maintain and report on their levees and an integrated process with emergency planning,

significant improvements to our understanding and management of levees will be achieved.