DEVELOPING A SYSTEMATIC APPROACH TO MONITORING THE CONDITION OF LEVEES IN NSW

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Abstract

Levees provide vital armour to reduce the potential impacts of flooding on a wide range of New South Wales communities. However, levees are particularly vulnerable to the environment. They need to be regularly maintained in accordance with asset management plans.

Regular visual condition audits can provide the basis for monitoring the effectiveness of maintenance activities in achieving the aims of the asset management plans. They can help to identify issues that may require a change in maintenance practice or rehabilitation or upgrade works to ensure that the levee can continue to provide its intended level of service.

The Office of Environment and Heritage (OEH) engaged the NSW Public Works to develop a methodology and guidance for the visual auditing of levees. This paper will discuss the final methodology and guideline and its application. It will also outline a systematic approach to these audits and the support that may be able to be accessible to councils to implement this approach.

Introduction

Urban levees play a vital role in reducing the impacts and risk of flooding on the community for floods up to their design flood event. Levees systems generally involve an earthen and/or concrete structure in combination with other operational assets, including gravity and/or pumped drainage systems, floodgates and temporary sections. They often require significant upfront investment from communities and government and are generally designed to provide protection for an extended period, with earthen levees expected to have a design life of at least 40 years with regular maintenance.

The maintenance of flood mitigation structures has been identified as an area for concern across Australia. Routine monitoring, maintenance and reporting on the condition of a levee system and prompt identification of defects can reduce the potential for levee failure. This ensures the benefits of investment in the levee are realised for its design life.

Effective monitoring, maintenance and reporting of levee condition enables:

- specific defects to be monitored and rectified so the levee remains fit for purpose for its design life.
- the reliability of the levee and key issues affecting this reliability to be understood and monitored as condition deteriorates or rectification works are undertaken.

- rectification works to be completed as early as practicable to limit further deterioration, repair costs and additional risk exposure of the community.
- the levee owner to develop contingency plans to deal with defects where repairs may not be completed before the next flood.
- relevant government agencies including flood risk managers (the Office or Environment and Heritage, OEH) and emergency services (NSW State Emergency Service, NSW SES) to be kept up to date on the levee condition and the owner's contingency plans so these can be considered in developing effective response and recovery plans.

Physical failure of a levee and hence flooding of protected area can place lives at risk, create major operational problems and threaten the viability of the protected community and the wider community normally serviced by the flooded town. Clean up and recovery is likely to impose a significant cost burden on the local and wider communities and all levels of government.

Early identification of developing maintenance and structural issues is necessary to minimise the potential for failure and the associated impacts, and to reduce the potential for significant degradation requiring major rehabilitation. Regular and frequent visual inspections and audits undertaken by suitably qualified and experienced staff are seen as the most cost effective way of identifying potential problems.

To help ensure that such inspections and audits are undertaken to a reasonably consistent standard across the state, OEH worked with NSW Public Works to develop and trial a visual levee audit and inspection regime and monitoring and reporting system. This provides technical staff with the basis for future visual levee audits and inspections. It enables effective tracking of changes in levee conditions and rectification works, and facilitates communication with other stakeholders such as NSW SES and OEH.

Funding assistance for this project was provided through the Commonwealth's Natural Disaster Resilience Program managed in NSW by the Ministry of Police and Emergency Services (MPES) and for the Commonwealth by the Attorney General's Department.

MPES has subsequently funded additional work (some of which is continuing) on:

- prioritised audits of levees particularly where upgrades or audits have not occurred within a reasonable time period.
- the development of a database of information on levees to enable improved government access to information when a flood threat does occur.
- the development of a levee owner's guideline to guide levee owners in developing their own levee owner's manuals. These manuals aim to assist in ensuring accessibility and discoverability of accurate and up to date information on the levee (including the supporting documentation discussed in this paper) where there is a change in staff and between local and state government. An owner's manual would seek to provide access to:
    - documented information on the levee (from work as executed plans where available).
    - the operations and maintenance manual for the levee, which is kept up to date considering advice from external and internal audits.
    - current knowledge and condition of the levee, considering external and internal audits.

- practical and implementable contingency planning which has been developed and documented to temporarily address levee defects in the lead up to an event if rectification works for major defects may take some time to complete.

The guideline also encourages sharing of information on levee condition within government to inform emergency response and flood risk management planning through the development of a simple communications plan.

- The development of several trial levee owner's manuals based around existing operations and maintenance manuals.

Audit Regime for Levees

Effective monitoring and reporting on the condition of a levee is essential to identify issues that may need to be rectified or further investigated, to enable the levee to fulfil its design function for its maximum economic life.

To satisfy this requirement an audit and reporting regime is recommended that involves survey of the levee crest, more frequent visual audits of the levee which result in a report that outlines the levee condition, tracking of rectification work required or conducted since the previous audit, issues to be monitored, and communication of outcomes to relevant staff and government agencies who need to consider this in their planning or operations.

An audit is more formal than an inspection. It involves a systematic assessment of a levee, not only reporting what is seen (good and bad) but interpreting it, highlighting problems and issues and recommending a course of action (which may include the need to seek additional advice or undertake additional investigations). This requires more rigour than an inspection and the right perspective which considers the potential consequences of a flood to the community and how the flood and levee system interact. An inspection is reporting what is seen and usually only reporting what the problems are.

The audit regime recommended in this report involves the following components:

- **Survey of the levee crest, where required:** This would generally be undertaken every 5 years preceding the detailed visual levee audit so it can be used in its preparation and included in the audit. This could be undertaken by a qualified surveyor or survey technician. The survey should have access to the work-as-executed plans and any subsequent crest level surveys so that changes can be identified.

- **Detailed visual audits of the levee system:** These would usually be undertaken by an independent party, such as NSW Public Works and therefore be considered external audits. They would normally occur every 5 years and may also be undertaken after a major flood where significant damage to the levee system is visible. They would be undertaken by a professional engineer with civil or geotechnical engineering qualifications and appropriate civil engineering, earthworks, concrete works, pipe laying and pumping experience.

  No geotechnical investigation or other types of investigations are undertaken as part of this visual audit methodology. However, the audit may identify defects that warrant further intrusive investigations and make recommendations accordingly. Ideally a detailed visual audit report would be available to inform general visual audits.

- **General visual audits of the levee system:** These may be undertaken by an appropriately qualified staff member of the levee owner and be considered internal audits. While it would be ideal for the auditor to have civil or geotechnical engineering qualifications, these qualifications are not essential. The auditor should have experience in the techniques used in the construction of the levee and associated works. This may include earthworks, concrete works, pipe laying, flood gates and potentially pump systems and sheet piling.

  The auditor may also have undertaken specific training in Dam Safety Surveillance through the NSW Dams Safety Committee. However, there are cases, particularly where the defects identified are likely to seriously jeopardise the performance of the levee relative to its design, where additional professional expertise may need to be sought.

  These would normally be undertaken on an annual basis (as a minimum) and may also be undertaken after a flood or other significant event such as earthquake, riverbank erosion or slumping, where damage to the levee system may occur. Previous audits and surveys, where undertaken, can be used to inform the site inspection and the new audit can concentrate on monitoring changes in existing defects, the identification of any new defects that have appeared since the previous audit, and associated reporting.

  The site inspection and new audit would also be assisted by documentation on the levee and the Guide Notes documented in the levee audit methodology report.

Documentation to Support the Visual Auditing Process

Documentation on the levee should exist with the levee owner but would need to be complied (from all sources) to ensure that the levee and its operation and the maintenance regime is understood to inform the visual auditing process, where for a detailed or general audit. The necessary documentation includes:

- Relevant reports – flood studies, floodplain risk management studies and plans, particularly those that relate to the design of the levee or examine its performance. This will provide information on design floods.
- Design criteria for the levee including design drawings, specifications and documentation (where available).
- Work-as-executed (WAE) drawings of the levee and its key supporting features.
- Information on the infrastructure and community at risk behind the levee system and protected by particular portions of the levee system which may act independently and therefore fail in isolation. This will provide information on size and extent of the community protected.
- Operation and maintenance manuals for the levee.
- Previously completed audit reports, both detailed and general, including any recommendations for rectification works.
- Rectification works or changes to the levee since the last audit (including WAE drawing where warranted).

This documentation may form part of, or be referred to, in a levee owner's manual.

Reporting templates and guide notes are available to assist in undertaking visual audits.

Reporting on visual levee audits

The hierarchy of levee zones, shown in Figure 1, concentrate attention to those areas of more importance during an audit, whether detailed or general.

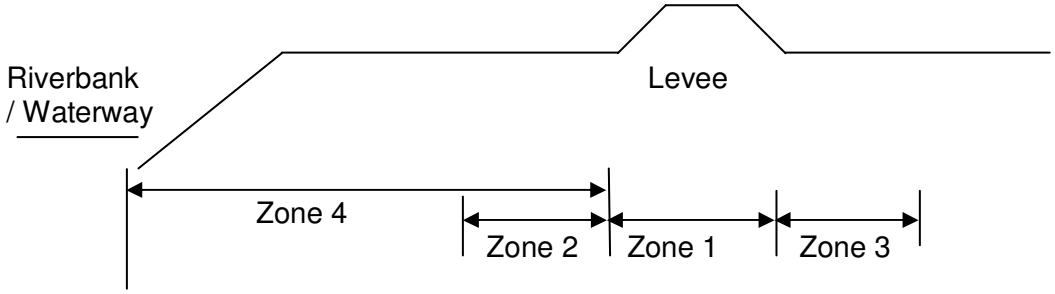

Figure 1: Levee Zones

Note:
Zone 1 *Levee footprint (including any footings for concrete levees)*
Zone 2 *4 - 5m from the levee toe / levee footing toe on the river/water side of levee*
Zone 3 *4 - 5m from the levee toe / levee footing toe on the town side of levee*
Zone 4 *Riverbank / waterway frontage (within 50m of the toe of the levee)*

Typical risks within the zones include:

Zone 1	**Risks are critical as they could affect the structural integrity of the levee.**
Zone 2	Water can weaken structures adjacent to the levee which can adversely affect its structural integrity.
Zone 3	Works on inside of levee e.g. house developments, can also adversely affect the structural integrity of the levee. Water can weaken structures adjacent to the levee which can adversely affect its structural integrity.
Zone 4	Water and waves from boats can undercut the riverbank leading to slumping. Where the levee is close to the riverbank, this can result in significant risk of failure. These issues are often more long term (e.g. riverbank erosion) and rectification can be difficult.

The template provided in this report relies upon visual audits and proposes a simple four (4) tier rating system to describe the type of risks identified with each issue that may arise on a levee system.

The recommended ratings are:

✓	**Acceptable**	If an item is rated as acceptable, no specific action outside regular maintenance regime is required.
±	**Marginal**	If an item is rated as marginal, an action is required to remediate the issue. These issues do not affect the structural integrity or functionality of the levee. This defect should be monitored and, where recommended, rectification works undertaken.
✖	**Unacceptable**	If an item is rated as unacceptable, an action is required to remediate the issue. These issues do affect the structural integrity and/or the functionality of the levee but do not pose an imminent threat in the event of a flood. This defect should be monitored and where recommended rectification should be planned, contingency plans developed and other government agencies, such as OEH and the NSW SES, informed where warranted.
☠	**Imminent Threat**	If an item is rated as an imminent threat, an action is required to remediate the issue. These issues mean that they do not meet the levee design criteria and pose an imminent threat to the structural integrity and/or functional intent of the levee in the event of a flood. This defect should be rectified as per recommendations as a priority. Contingency plans should be developed to deal with the additional flood risk until rectification works are completed. Other parties, such as the NSW SES and OEH, need to be informed so this can be considered in flood risk management and emergency response planning.

Levee Reporting Segments

Undertaking and reporting on all level audits can be made easier by dividing the levee into segments of similar levee types and by noting levee chainages where possible from plans. Divide the segments into sections with similar levee conditions with likely similar risk issues. For example one earth levee section with minimal adjacent trees and not near river bank compared to another earth levee section with adjacent trees and immediately adjacent to the river bank.

Where suitable, the same segments as used in previous audits should be used. These can be grouped into like sections in the report. Levee sections through residential properties should be separate from levee sections through other land use areas. Ideally the maximum section length should be approximately 500m, unless the levee is exactly the same for longer lengths, for example, through open paddocks.

Field Inspection Methodology

The most effective means of conducting the field inspection is to treat each levee segment as an individual element, inspect it thoroughly, and record all relevant information and observations prior to moving on to the next segment. These observations should be checked against information in the guide note to identify the type of issue and to understand its seriousness.

The sequence for inspection of each levee segment is as follows:

a. **The crest:** walk along the top of the levee from one end to the other and look for general longitudinal alignment, erosion, depressions (puddles), settlements, rutting or cracks in the paved or unpaved surface or animal burrows, vegetation cover etc.

b. **The riverside of the embankment:** walk along the waterside of the levee bank in a zigzag, top to bottom fashion observe batter slope, vegetation cover, erosion, depressions, ruts, puddles or wet areas, slumps, woody vegetation or animal burrows.

   Note the proximity and condition of the river/creek bank including slope, erosion and vegetation cover.

c. **The townside embankment:** walk along the townside face of the levee bank in a zigzag, top to bottom fashion to observe batter slope, vegetation cover, erosion, depressions, ruts, puddles or wet areas, slumps, woody vegetation or animal burrows.

   Note the nature of the area adjacent to the townside of the levee including features such as excavations, buildings, fences etc. which may impact on levee performance.

d. **Stormwater pipes, gate valves and pump stations:** Observe the condition of the inlet/outlet culverts on the waterside and townside headwalls. Check for erosion, cracking or slumping around the structures. Check the condition of the pipes and floodgates/flaps and to note any blockage or cracks and the condition of locks and hinges including ease of opening.

   As part of the overall audit the operation of all gates and valves over their full range needs to be confirmed. Check the condition of the outside and inside of the gate valves, their ease of turning, identify rust, cracks, spalling, deterioration, etc.

   Check the condition of any pump stations for signs of rust and wear. Where possible, run the pump and any backup and where this is a fuel pump note when the fuel was last replaced as this may go stale.

e. **Test automatic release of automated floodgates where possible**. Check the condition of bolts, collar, hinges gate seal, floating barriers, if any, and function of all floodgates and flaps. Check for vandalism and debris that may affect operation.

f. **Services**. There may be other household, Council or utility services located within or through the levee and these may lead to failure of the levee. Background information (plans, records, photographs etc.) should be sought prior to a visual inspection, to assist in locating these hidden or less obvious services (or at least for recording their presence).

g. **Temporary Measures**. The need for temporary components to be deployed should be noted along with any on-site issues that may affect deployment. As part of the overall audit, the fitness for purpose, adequacy of storage, security and accessibility to where these levee components need to be deployed should be documented.

Experience has shown that an efficient way to undertake the above inspection is to walk along the top as well as one batter in a zigzag pattern. At the end of the segment, return to the starting point by walking along the top and the other batter in a similar zigzag pattern. The field inspection must also include adjacent zones beyond the levee zone (i.e. Zone 1) to identify and record other issues that may affect the levee.

Limitations of Audits

Any levee audit and particularly a general visual levee audit, is limited in its potential to assess issues due to a number of factors including:

- Background information available (often scarce and anecdotal) particularly for some of the older levees. However, the levee owner can assist by making the effort to find any relevant information available. If this is done once it should be scanned and kept in the levee owner's manual or operations and maintenance manual so it can be readily available for future audits.
- What can be seen above ground? Typically only specific testing, background data and or history can identify potential issues below the surface of the structure.
- The audit cannot economically look under every blade of grass and find every potential risk or issue. It should however, be able to determine potentially problematic issues.
- Ability to access the whole levee.

Any such limitations should be noted and included in the report on the audit

Reporting on the Audit

Documentation of the audit is important to ensure that issues identified can inform decision making in relation to the operations, maintenance and upgrade of the levee. The project developed a reporting template to provide the basis for both reporting on current condition and tracking condition overtime. The latter can highlight where problems have deteriorated and where rectification may be necessary or the most economical approach to reduce the need for greater rehabilitation efforts in future.

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

- Describe the levee being audited.
- Describe when, by, and with whom the levee was audited.
- Outline any limitations on the levee audit (as discussed above).
- Review the available documentation for the levee and outline any associated issues with the adequacy of the available information.
- Outline issues with the levee including details of the type of problem and its physical location (within a particular levee segment and related to a particular chainage).

- Separately identify and report each issue or risk to the levee in the report. Include a photo of the issue so that this can be used for checking condition against examples of different types and degrees of problems given in the guide notes. It can also allow for comparison of changes in condition over time to check on rates of deterioration or confirm rectification has occurred.
    - Rank issues in relation to their risk to the levee and their severity (Imminent threat, unacceptable, marginal and acceptable) so this can inform priority for treatment and monitoring. Rankings would be shown in both a table with locations shown on a drawing of the levee.
- Provide advice in relation to the types of rectification works necessary.
- Provide an overview of overall levee condition.
- Outline any recommendations on further investigations and improved documentation.

Dealing with the Findings of the Visual Audit

An audit report can identify a range of defects with the levee, its management and the available documentation that need to be rectified so the levee can be monitored and maintained in a condition that is fit for purpose for its design life. It may lead to the need for the levee owner to:

- Improve documentation of the levee. This may relate to :
    - Adequacy of information on the levee.
    - Accessibility of information on the levee and adequacy of information sharing. Where issues may affect the reliability of the levee it is important that this information is provided to those who need to know in council and to the relevant government agencies, NSW SES and OEH, so this can be considered in flood risk management and emergency response planning and community awareness. This may be facilitated the development of a simple communication plan to ensure current information is available across government.
    - Adequacy of the operations and maintenance plan.
- Work on the levee to rectify defects. Rectification works should be completed in a timely manner consistent with the advice in an audit to limit further deterioration, repair costs and exposure of the community to additional flood risk. This may be achieved through the inclusion of associated works into:
    - A levee rehabilitation plan. This may be considered where major works are required that would be beyond the general scope and scale of works included in the levee maintenance plan and may have significant resource implications.
    - The levee maintenance plan. This is suitable for the inclusion of works consistent with the general scope and scale of works in the levee maintenance plan and the types and scale of resources available under the plan. Additional resourcing may be necessary to address the issues raised by an audit.
    - Development of contingency plans to address major defects identified with the levee until rectification works have been completed. Where rectification works require significant resources and time to complete, particularly where they may involve significant investigation and design activities, contingency plans may need to be developed in case a flood occurs prior to defects being rectified. Contingency plans should consider the available flood warning and the available council resources, equipment and material and be fully documented so they can be readily

initiated when required. Contingency plans need to be included in the levee operations plan and inform local flood emergency response planning.

The ability to instigate a contingency plan within the available timeframe **should not** reduce the importance or priority in addressing major defects in the levee.

- Undertake additional work on monitoring defects and levee condition. This may involve:
  - Altering the levee maintenance plan to facilitate recommended monitoring and reporting of changes in conditions of specific defects in the levee.
  - Update of the levee operations plan. Where monitoring of condition or instigation of contingency plans is required during events.
  - Instigation of a levee audit regime as recommended in this paper. This involves regular internal audits (at least annually) and 5 yearly external audits to compare and report on current levee condition compared to that identified in previous audits.

Conclusions

Strategic management of levees can generally be accomplished through improved documentation, management, monitoring and reporting on levees. This paper outlines the levee audit regime outlined in the Methodology for Visual Auditing of Levees Report prepared by NSW Public Works for OEH.

The methodology and the associated tools provide a sound basis for visual audits, monitoring and reporting on the condition of levee systems. This will aid the management of levees and the knowledge of levee condition prior to flood events to facilitate effective flood risk management, contingency, response and recovery planning and community response to a flood event. It provides a sound basis for improving the strategic management of levees so that they are fit for purpose when a flood occurs.

This visual auditing methodology and regime will be refined as parts of future audits and the methodology and the associated tools will be made available through a relevant website. A number of projects continue that will aid at improving the strategic management of levees and the associated flood risk.

References

NSW Public Works. *Methodology for the Visual Auditing of Levees*, 2013.

McLuckie D, Spain F, Dixon J, Monitoring the *Condition of levees to inform decision making*, Floodplain Management Association Conference Batemans Bay February 2012.