Successful performance of detention dams in the February 2004 Manawatu floods

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Abstract

The Manawatu floods of February 2004 were an extreme event, causing widespread damage over a wide area. The townships of Scotts Ferry and Tangimoana, located adjacent to the Rangitikei River, were inundated, as well as parts of Feilding. Large areas of the Manawatu River flood plain were also flooded. A number of stopbank breaches associated with this flooding have been widely publicised. However, the successful performance of a large number of detention dams subjected to the same extreme event has not been recognised. These dams total 53 in number and are owned by Horizons Regional Council. These dams fulfilled their design function of limiting flooding and, in particular, limited flooding in the towns of Hunterville and Marton and in Wanganui East. Most dams were subjected to the greatest flood event since their construction, and in most cases the spillways operated for the first time. This paper describes the background of the dams, the flood event, and observations made of their performance, and describes the damage to a few dams. Risk areas for typical detention dam designs are then discussed, followed by historic management aspects of the Manawatu dams in the context of the pending dam safety legislation and possible impacts on their ongoing management.

Keywords: Detention dam, Porewa, Tutaenui, Matarawa, Manawatu floods

Introduction

The February 2004 storm event in the Manawatu and Rangitikei areas caused widespread damage, including flooding and landslides. The devastation took place mainly within the boundaries of the Manawatu-Wanganui Regional Council (Horizons RC). The towns of Feilding, by the Oroua River, Scotts Ferry and Tangimoana, by the Rangitikei River, were the worst affected residential areas together with a large part of the Manawatu River flood plain.

Horizons RC is responsible for the management of a significant asset of flood protection works including:

a) the Lower Manawatu scheme, which protects Palmerston North City and rural areas from flooding by the Manawatu River and its tributaries;

b) the Lower Rangitikei River scheme, which protects Scotts Ferry and Tangimoana; and

c) 53 flood detention dams; the most significant schemes being the Porewa (27 dams), Tutaenui (18 dams) and Matarawa (5 dams).

Whilst the stopbank breaches which occurred during the flood were well publicised, very little focus appears to have been placed on the successful performance of the flood detention dams owned by Horizons RC.

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Description of flood detention dams and background

General

The paper will focus on the three main schemes which were visited by the writer at the request of Horizons RC soon after the 2004 flood event. The locations of the schemes are shown in Figure 1. All of the dams were constructed in the period from 1960 to the early 1980s, and they are typically located on tributaries of the main stream responsible for flooding. A similar design concept was used for most of the dams. They were constructed as homogenous earth dams, with heights ranging from 3 m to 10 m. Spillways are generally grass covered channels cut into natural ground. Some of the earlier dams had concrete spillways. The pipe beneath the dam for taking normal stream flows was laid through sound *in situ* materials, with a standard flume and energy dissipater at the outlet. The regional geology varies over the three schemes; it is typically Upper Tertary age soft mudstones in the Porewa scheme, mid-Quaternary age marine terraces for the Tutaenui scheme and lower Quaternary siltstones, sandstones with shell beds for the Matarawa scheme. Some dams are located on alluvial deposits within the valleys, particularly on the Porewa scheme. A summary of key scheme statistics and features is shown in Table 1 with a photo of a typical dam in Figure 2.

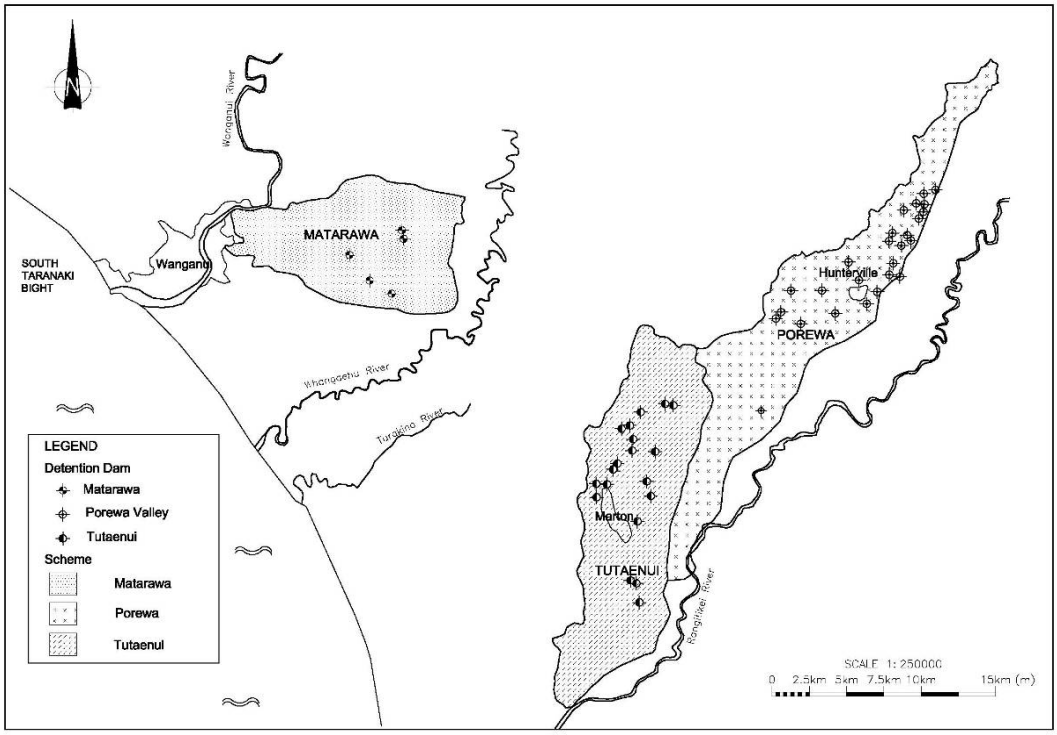

Figure 1. Matarawa, Porewa and Tutaenui flood control schemes

Table 1. Key statistics and features of the Horizons RC flood control schemes

Scheme	Number of Dams	Townships Protected	Largest Storage Volume (m^3)	Number in Hazard Categories (based on NZ Dam Inventory Published by Ministry of Commerce)		
				High	Medium	Low
Porewa	27	Hunterville, Rata	678,400	2	1	24
Tutaenui	18	Marton	113,000	-	4	14
Matarawa	5	Wanganui outskirts	360,000	-	-	5
			Total	2	5	43

Typically the reservoir storages were designed for a 20- to 25-year event prior to operation of the emergency spillways. The emergency spillways were typically sized for a 100-year event, with an allowance for freeboard.

Figure 2. View of typical dam in the Matarawa scheme

Performance in the 2004 flood event

Hydrology

Table 2 below shows the flows and return periods for the 2004 event on major rivers in the area (Horizons Regional Council, September 2004). Of the flood control schemes, the Porewa and Tutaenui rivers are tributaries of the Rangitikei River while the Matarawa, which is adjacent to the Whangaehu catchment, flows into the Wanganui River.

Table 2. Peak flows and return periods

River	Location	Peak Flow (m^3/sec)	Return Period (years)
Manawatu	Palmerston North	3501	70
Whangaehu	Kauangaroa	1935	≈ 200
Rangitikei	Mangaweka	1746	40-50
Turakina	SH3	957	120-200

The return period for the flood in the Manawatu River was 70 years, taking account of the 2004 event, and 110 years based on the 1992 flood frequency analysis.

Rainfall totals exceeded 100 mm in 24 hours at 22 of the 38 rainfall sites in the region, with three of these sites totalling over 200 mm in 24 hours. No specific flow recorders were located in the catchments of the detention dams and detailed hydrologic analyses have not been carried out. However, the detention dams are located within the areas of most intense rainfall. Rainfall contours indicate that the return period of the event may well have been in the order of a 50- to 100-year event.

During the event, most spillways operated (many for the first time) but no dam overtopping was recorded. As the dam storage was typically based on a 25-year event this is consistent with an extreme event. The event is certainly the biggest test the detention dams have been subjected to, in common with the overall flood protection schemes operated by Horizons RC.

Observations after flood event

Overall the 53 detention dams owned by Horizons RC performed well in the flood event, with no breaches causing an uncontrolled release of the reservoir. The townships of Marton and Hunterville within the flood control scheme catchments were still subject to some flooding, but the degree of flooding would have been much more severe without the storage provided by the detention dams.

The writer inspected a number of dams and areas of damage several weeks after the event. The following key points were observed.

- No dams appeared to come close to overtopping. Most spillways appeared conservatively designed, with typically 200 to 600 mm freeboard above the 100-year event.
- Grass spillways performed in general very well, with only minor erosion. This appears to be due to very good grass cover and mild slopes.
- Significant damage to spillways was observed in two dams. One was related to headward erosion where the spillway terminated in a very steep slope down to the main stream. The second was due to spillway flow reactivating a pre-existing slip on which the spillway was located (see Figures 3, and 4). Significant repairs were required to the spillway in each case, but neither event endangered dam integrity.
- Most dams showed no evidence of seepage through the dam or foundations. On one dam in the Matarawa scheme some minor voids adjacent to an outfall structure and outlet pipe were possibly due to seepage and erosion.
- During and immediately after the event, Horizons RC staff were able to inspect the dams by helicopter, and physically inspect them later.
- Priorities for further inspections and remedial works were identified by Horizons RC. Due to the massive scale of damage to the flood protection assets owned by Horizons RC, this prioritisation was essential. Only one area of damage in the three dam flood control schemes was considered to be an urgent repair.

Figure 3. Slippage on spillway of Porewa No. 62

Figure 4. Damage to spillway channel of Porewa No. 62

Typical risk areas for detention dams

Detention dams have been used extensively for some time in New Zealand and overseas, mainly in developing urban areas. They often serve several purposes, i.e., both for flood detention and, in some cases, maintaining water quality. Although the size of the dams and storages are typically modest, the hazard created by the reservoir in an urban area may well be greater than is immediately obvious. Hence it is likely that quite a number of detention dams will be categorised as medium or even high Potential Impact Category dams by the criteria in the NZSOLD Dam Safety Guidelines. In the author's experience, there are a number of potential risk areas.

Many detention dams are located in urban parks or have the embankment forming a roadway. Their spillways are often not cut into natural ground, resulting in more risky designs such as spillways over the dam itself. Whilst these can be designed to minimise risk of dam failure, the concept is inherently more risky than using a spillway cut into natural ground. Trees, vegetation and fences often present a risk of blockage of the spillways. The spillways for the Horizons RC dams were cut into natural ground and performed well.

Blockage of primary pipe outlets during a flood is a significant risk—this emphasises the importance of a conservatively designed emergency spillway.

All dams have a low-level pipe penetrating the dam, presenting an obvious risk of problems with seepage and erosion. This is often exacerbated by soft founding soils. Seepage/erosion-related incidents are invariably related to uncontrolled seepage along sides of an outlet pipe or headwall, even in relatively modest floods.

In the author's experience it is rare for defensive measures such as filter protection of the pipe outlet to be incorporated in the design. Seepage collars are often incorporated, even though their use is now an outdated concept in modern dam engineering practice. Many engineers still believe collars represent conservative practice and they are still promoted in some regional council publications. Lack of seepage protection on an outlet pipe for a medium or high potential impact dam is unlikely to be considered good practice by modern design standards for a new dam.

Horizons RC detention dam management aspects

Existing regime

The 53 detention dams form only a relatively small part of the flood protection assets owned and managed by Horizons RC. The stopbank systems and related structures are also more significant in terms of the assets they protect; for example, stopbanks protect the urban area of Palmerston North from flooding by the Manawatu River.

The main elements of safety assurance by Horizons RC, with respect to the detention dams, are discussed below.

All dams are inspected after significant flood events by Horizons RC staff and at least twice a year to identify any maintenance requirements. A database is kept on ponded levels in flood events and maintenance requirements.

In 1997-1998 Horizons RC commissioned independent consultants to review the safety of all the dams in each scheme (Woodward Clyde 1997; Woodward Clyde 1998; Riley Consultants Ltd 1997). These included a review of the hazard or potential impact ratings published in the then recently published New Zealand Dam Inventory (Ministry of Commerce 1988). In general the independent reviews concluded that the dams were in an acceptable condition, in places requiring some minor improvement works or improved monitoring.

The reports identified that emergency response was an issue that did not appear to have been fully considered. The independent reports identified that reconnaissance of the dams during a major flood event would be important to provide early warning of any potential problems. The reality is that due to the wide geographic spread of dams and limited resources this ideal is not achievable in an extreme event.

At the time (i.e., 1997-1998) there was no regulatory requirement to undertake independent safety reviews of the detention dams owned by Horizons RC. The construction of the dams predated the 1991 Resource Management Act. Even though the dams had not experienced significant problems, Horizons RC was aware that independent review would be prudent in 1997-1998.

Effects of proposed Building Act Regulations

a) General

The implementation of the Regulations associated with the Building Act introduces a new era in dam management. Through the flood control schemes Horizons RC is the owner of a large number of dams, and under the new Building Act, it is also the regulator.

The 2004 flood event was a significant test, in terms of both structural performance (flood at or near the maximum design event), and management response.

The successful performance of the dams during the flood, and the identification of damage and subsequent repairs carried out indicated that no significant weakness in either area was present. It is possible Horizons RC could apply to become an accredited dam owner; however, with or without accreditation the tests for compliance on elements of dam safety assurance are NZSOLD's Dam Safety Guidelines.

For a dam owner such as Horizons RC, being an accredited owner will likely require a significant increase in both resources and staff commitment. It would appear the NZSOLD Dam Safety Guidelines would form a "best practice" document for this process, and familiarity with the document would be required. The Regulations will likely require individuals managing the dam safety assurance process to be accredited; not just Horizons RC.

b) Classification of dams

Most dams have already been assigned a rating by Horizons RC. It would be a relatively modest task to review the ratings in terms of the criteria in the Regulations when they are implemented. The most significant challenge may be confirming whether dams at the upper end of the low category close to residential areas do not pose a significant threat to dwellings in the advent of failure.

c) Dam safety assurance programme

In terms of the proposed Regulations (Department of Building and Housing 2006) the elements of the programme must include:

- surveillance requirements and frequency,
- requirements for annual dam safety reviews,

- requirements for special or emergency inspections,
- requirements for comprehensive safety review
- an emergency action plan (EAP), and
- procedures for safety enhancement investigation, assessment and resolution.

As evidenced by the response to the 2004 flood, the essential elements of the above are already in place. A further stage of detail and documentation is likely to be required to fully comply with the intent of NZSOLD's Dam Safety Guidelines and the requirements of the final Dam Safety Regulations. Several points in the context of the detention dams are likely to be relevant.

In an extreme event, similar to the 2004 floods, resources will be severely stretched. What is practical will require close consideration in terms of emergency planning (for example, what emergency actions are possible). For the full benefit, any emergency action plan for the dams will need to fit into the overall framework of all Horizons RC assets. It is ironic that the entire stopbank system represents a far greater potential impact compared to the detention dams, but it is not covered by the proposed legislation.

The NZSOLD Guidelines (in common with most dam engineering literature) does not provide much detailed guidance for either the design or safety management of flood detention dams.

Conclusions

- The 53 detention dams owned by Horizons Regional Council performed well in the 2004 Manawatu floods. No breaches occurred, and the dams fulfilled their primary design objective of reducing flooding to downstream areas (in particular the towns of Hunterville, Marton and the outskirts of Wanganui).
- Many dams filled to full storage capacity for the first time, with their overflow spillways operating. This is analogous to first filling for a permanent dam.
- Conservatively designed grassed spillways (with freeboard above 100-year flood level) generally suffered only minor or no erosion. In a couple of instances erosion damage requiring repair occurred, but neither represented a significant threat to dam integrity.
- During and immediately after the event, inspections of the dams identified the main problems, and priorities for repair. However, this damage represented a small fraction of the damage to the flood control assets owned by Horizons RC.

Acknowledgements

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