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INCIDENTS AT GATED SPILLWAYS IN SOUTHERN AFRICA (*)

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1. INTRODUCTION

In a lot of cases gated spillways are seen as a more economical option than uncontrolled spillways as there are normally significant savings as less freeboard is needed for gated spillways compared to uncontrolled spillways. In most cases the inherent higher risk of failure of gated spillways is however not considered when comparing the two options with each other during design. This is only considered when using risk management principles during design which is not general accepted practice.

To minimise the risk of failure of gated spillways during the lifespan of a dam, it is important that the gated spillway system is properly designed, operated (taking into account human inputs as well as mechanical and electrical efficiency)

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and maintained. Non-compliance of any of these requirements significantly increases the risk of failure. This paper highlights the importance of these requirements through case studies of incidents that occurred at three dams with gated spillways in Southern Africa; namely Hardap Dam in Namibia, and Bospoort Dam and Lake Arthur Dam in South Africa.

2. HARDAP DAM

Hardap Dam is located on the Fish River, some 17 km north north-west of the town of Mariental in the southern part of Namibia. The catchment is large (13 550 km^2) and the dam functions primarily as storage of water for irrigation, domestic and industrial use. It is the largest dam in Namibia with a total storage capacity of 295 million m^3. The downstream irrigation scheme is one of the main food producing centres of Namibia.

The dam was completed in 1963. It is currently owned and operated by the Namibia Water Corporation Ltd (NamWater). The 35.9 m high dam wall is a composite structure consisting of a centrally located, controlled ogee concrete gravity spillway, with four radial gates (each 11.1 m high and 11.6 m wide) flanked by asphalt concrete faced rockfill embankments as well as other secondary embankments. An auxiliary spillway is located on the outside of the secondary embankment on the left bank and a concrete apron is provided on the downstream toe of the spillway. The control system for the radial gates has three power sources – the national power grid, a standby diesel generator and a small mobile generator (that should be operated at each individual gate). The gate system is also tested annually before the flood season and effort is made to ensure that the local operating personnel are trained to operate the gates with any of the three power sources.

An extreme flood event took place from 24 to 26 February 2006 (see Figures 1 and 2 for a view of the spillway and a graphical presentation of the flows and water levels versus time respectively) [1]. Late during the night of 25 February 2006 the national power supply line failed. When trying to use the backup generator it also failed. Fortunately there was a third option (a small mobile generator that should be operated at each individual gate) as well as well-trained onsite personnel as an increase in the flood release was required during this period with two of the power sources not available.

Subsequent analysis has clearly indicated that the dam may have failed or suffered serious damage if the power failure occurred earlier (for example early morning of 25 February 2006) and the third power option was not available. This case study clearly highlights the importance of sufficient redundancy of especially power sources (preferably 3 options) as well as properly trained and well informed operating personnel.

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Fig. 1

Aerial view of the spillway of Hardap Dam spillway during the 2006 flood event

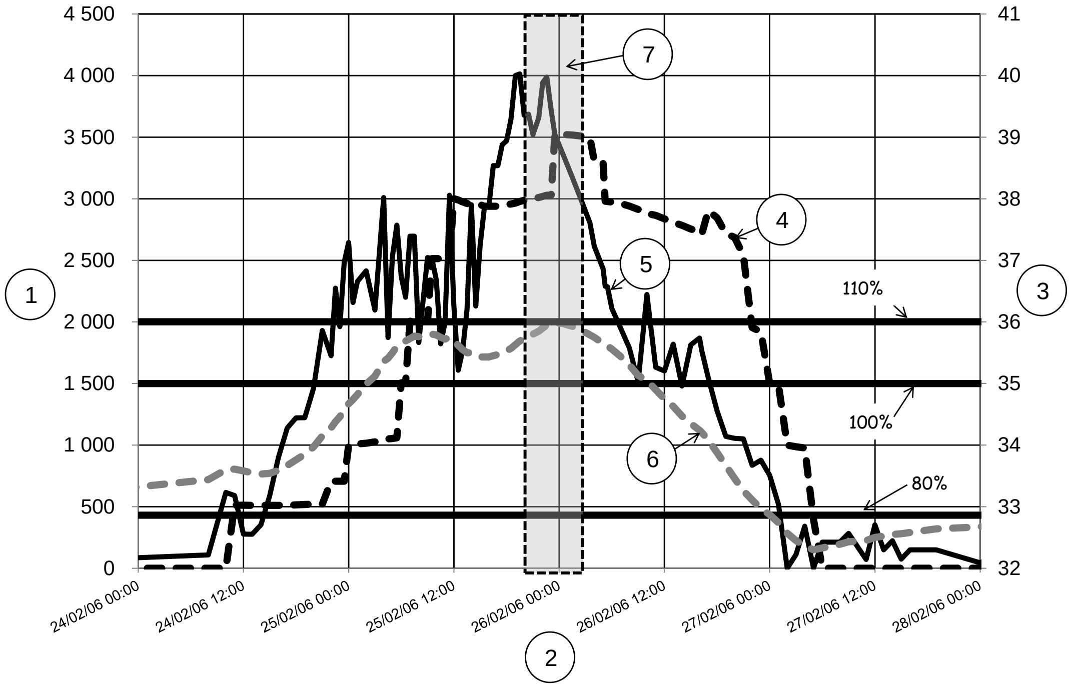

Fig. 2

Hardap Dam: 2006 flood event flows and water levels versus time

1	Relative distribution	*1*
2	Time	*2*
3	Water level (m)	*3*
4	Inflow (m^3/s)	*4*
5	Outflow (m^3/s)	*5*
6	Water level (m)	*6*
7	Period of power failure	*7*

3. BOSPOORT DAM

Bospoort Dam is located in the Hex River, some 15 km north-east of the town Rustenburg in the North West Province in South Africa. The catchment is medium sized. The water in the dam is allocated to Rustenburg Municipality for domestic use. The dam, designed, built, owned and operated by the Department of Water and Sanitation, was completed in 1933 and raised twice in 1953 and 1969. The particular incident described in this paper refers to the 5-yearly dam safety evaluation that took place during December 2004 [2]. The dam was subsequently rehabilitated.

The dam in 2004 consisted of a concrete gravity wall and three separate earthfill embankments, two of which are zoned. The concrete structure was originally constructed as a buttress concrete gravity structure in 1933. During 1953 it was raised and converted into a conventional concrete gravity structure. The final raising in 1969 entailed the addition of twelve radial crest gates and the anchoring of the gravity structure with post-tensioned cables. A controlled ogee spillway equipped with radial gates was situated on the right flank of the concrete gravity wall (see Figure 3).

The control system for the radial gates only had two power sources – the national power grid and a small mobile generator (that should be operated at each individual gate). In addition, the dam operator was not stationed at the dam. He was based 30 km away at another dam with no water level warning system in place. During the inspection it was first observed that water was flowing over the radial gates. When attempting to open the radial gates to lower the water levels (as the radial gates were not designed for overtopping flow) it was discovered that not only was the power cable from the national grid was stolen, but also the backup generator had issues to be started as it was not regularly operated and in addition 5 of the 12 gates' cables were completely corroded.

From the results of the dam safety evaluation [2] presented in Figure 4, it was clearly evident that the risk level encountered during the 2004 inspection was totally unacceptable with probabilities of failure of the dam of between 1×10^{-1} and 1×10^{-2}. It was also evident that risk level of the dam was still unacceptable even with the gated spillway fully functional (with probabilities of failure of the dam of between 1×10^{-2} and 1×10^{-3}). Subsequently the dam was rehabilitated by replacing the gated spillway with an uncontrolled labyrinth spillway and providing an additional uncontrolled labyrinth spillway on the right bank and raising the earthfill embankments. As a result the risk level of the dam is now acceptable.

This case study clearly highlights that the 2004 situation could be described as a failure waiting to happen. None of the requirements for the proper operation of a gated spillway system were complied with as there was not sufficient redundancy of the power sources, the operator was not stationed at the dam, the gates were not tested before each flood season and the maintenance were not up to standard.

Fig. 3
Gated spillway of Bospoort Dam during the 2004 dam safety evaluation

4. LAKE ARTHUR DAM

Lake Arthur Dam is located in the Tarka River approximately 20 km east of the town Cradock in the Eastern Cape in South Africa. The catchment is large (4 497 km^2) and the dam functions mainly as a balancing reservoir for irrigation use. The dam, designed and built by the predecessor of the Department of Water and Sanitation, was completed in 1924. The dam is currently owned and operated by the Great Fish River Water Users Association. The dam wall is a concrete gravity structure with an uncontrolled ogee spillway in the river section. Steps are provided on the downstream slope along the whole length of the dam wall. The full supply capacity of the dam was increased in 1939 by installing 66 sluice gates on the spillway crest. In 1945 the gates were extended to increase the full supply level by another 0.9 m. It is important to note that these gates were manually operated. These sluice gates were removed in 2002/03 as a result of a recommendation from the previous inspection reports due to a total lack of maintenance resulting in insufficient spillway capacity as a result of the inoperable condition of the gates [3].

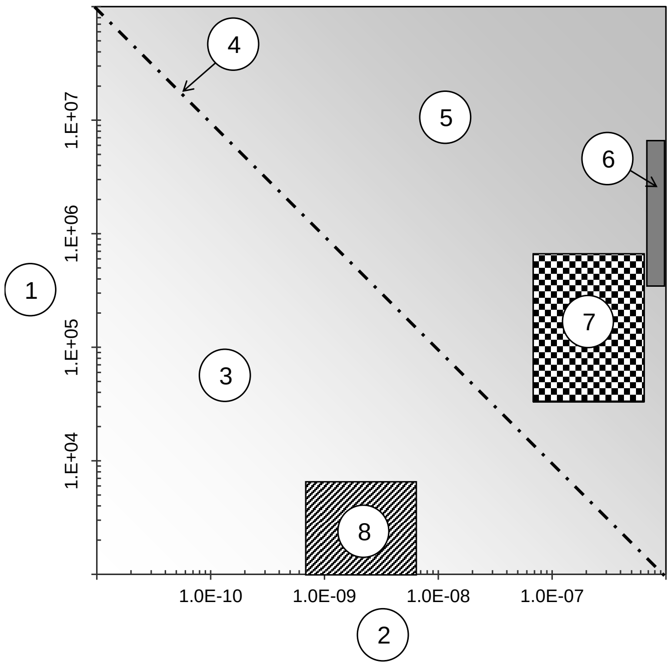

Fig. 4
Risk levels of Bospoort Dam

1	Risk of financial losses (R/annum)	*1*
2	Annual risk of fatalities per exposed hour	*2*
3	Acceptable risk level	*3*
4	Boundary of involuntary imposed risk	*4*
5	Unacceptable risk level	*5*
6	Risk level during 2004 dam safety evaluation	*6*
7	Risk level with gated spillway fully functional	*7*
8	Risk level with new uncontrolled labyrinth spillway system	*8*

An extreme flood event took place from 18 to 19 May 1950 (see Figure 5 for a graphical presentation of the water level versus time) [4]. Very early in the morning of 18 May 1950 the operator was informed that a flood was on its way. Around 4 am on 18 May 1950 the first gate was opened and an effort was made to open as many gates as possible. By 7 am a total of 20 gates were fully open. The water, however, started overtopping the non-overspill crest as the operator was not able to open enough of the gates. As soon as the overtopping started the operator feared for his own safety and abandoned the operation of the gates. As a result overtopping of the non-overspill crest took place for a total of 4 hours. No significant erosion damage of the downstream foundation was fortunately evident.

This case study clearly highlights the importance of making sure that the opening speed of the gate system is sufficient for the site conditions. Also the importance of redundancy of the power sources (in this case only one option was available) as well as proper regular maintenance (after more than 50 years of no maintenance the gates were no longer operable).

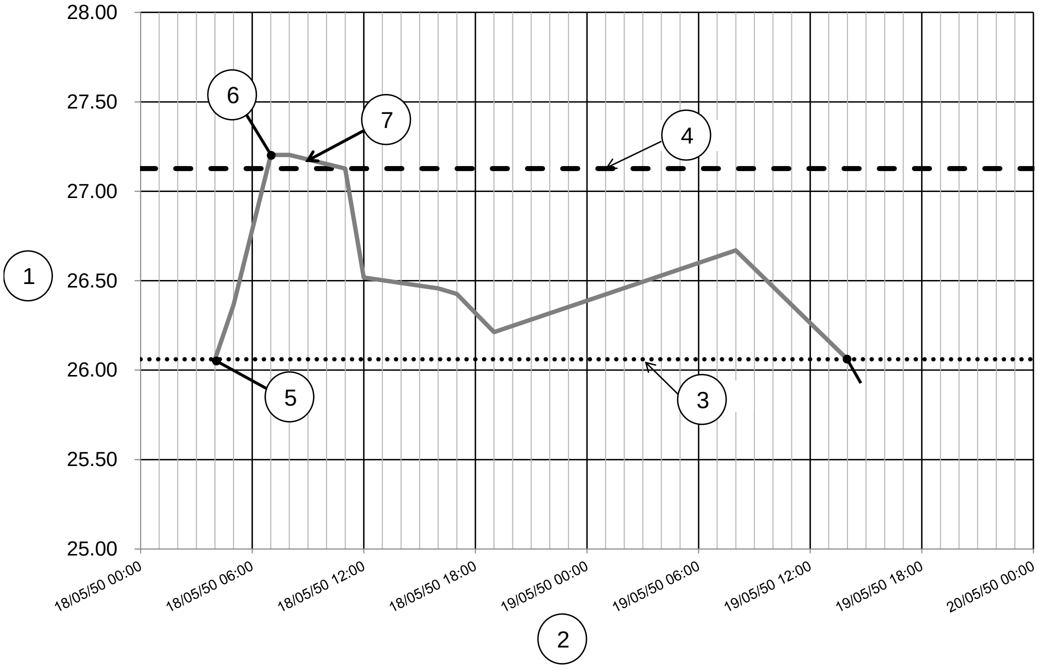

Fig. 5
Lake Arthur Dam: 1950 flood event water levels versus time

1	Water level (m)	*1*
2	Time	*2*
3	Full supply level	*3*
4	Non-overspill crest level	*4*
5	Start opening gates	*5*
6	20 gates open	*6*
7	Overtopping of the non-overspill crest	*7*

5. CONCLUDING REMARKS

When using gated spillways in especially developing country conditions it is clearly evident from the case studies that it is very important to ensure the following to reduce the risk of failure as far as possible:

- The design of the gated spillway system is appropriate to open the gates in time;
- Sufficient redundancy is provided for the operating system (especially the power supply);
- The operation staff is properly trained, stationed on site and the system is tested annually before the flood season; and
- All components of the gated spillway system are properly maintained on a continuous basis.

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REFERENCES

[1] Hattingh, L.C.. *Professional Assessment of Hardap Flooding Situation and Measures: Task 2e: Evaluation of flood routing procedures*. Report no. 11/11/3/1/2/H04. WRP Consulting Engineers, Pretoria, South Africa, 2007.

[2] Hattingh, L.C. *Second Dam Safety Inspection – Bospoort Dam*. Report No. A220/07/DY02, Department of Water Affairs and Forestry, Pretoria, South Africa, 2005.

[3] Hattingh, L.C. *Third Dam Safety Inspection – Lake Arthur Dam*. Report No. P0078/Q440/01/01, Hattingh Anderson Associates CC, Pretoria, South Africa, 2012.

[4] Carmichael, G.P. *Lake Arthur Dam: Dam Safety Inspection*. Letter report with no number. Department of Water Affairs, Pretoria, 1985.

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SUMMARY

This paper summarise some examples of major incidents involving gated spillways that has occurred in Southern Africa. The relative high risk of gated spillways are be highlighted in the light of the general perceived acceptability of using these types of spillways while not considering their relative risk.

To minimise the risk of failure of gated spillways during the lifespan of a dam, it is important that the gated spillway system is properly designed, operated (taking into account human inputs as well as mechanical and electrical efficiency especially providing sufficient redundancy) and maintained. Non-compliance of any of these requirements significantly increases the risk of failure. This is highlighted with the case studies of incidents that occurred at three dams with gated spillways in Southern Africa namely Hardap Dam in Namibia and Bospoort Dam and Lake Arthur Dam in South Africa.

RESUME

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6. TOPIC

QUESTION 97
SPILLWAYS

- Dam failures or incidents linked to gate operation: Reasons and case histories

7. KEY WORDS

Gated spillway
Risk analysis
Operation
Failure

8. LIST OF DAMS

Hardap
Bospoort
Lake Arthur