Wild waves.

by

J. L. Gordon.

George was feeling queasy. He was flying in a Huey helicopter along with a dam inspection and survey team. On takeoff, the pilot had mentioned that if the wind was a few knots higher, it would be too windy to fly. They were now flying north into a severe windstorm, which had been raging since the previous evening. They were on the annual inspection for dam safety, flying low over a series of dykes and dams forming a vast reservoir, inspecting the condition of the rip-rap, and looking for signs of slope slippage and seepage.

As they proceeded north, they realized that they were witnessing a test of the rip-rap, since the wind had increased, and with heavy downdrafts, the pilot was having more difficulty controlling the helicopter, having to keep further way, and fly higher than usual above the dykes, thus making the survey more difficult.

After crossing over a series of hills, they descended into the last valley containing the most northerly dykes, and were astonished to see in the far distance, what appeared to be waves washing over the dykes. Concerned, the head of the inspection team instructed the pilot to fly directly to the two dykes where the overflow spray seemed to be the most severe. Now circling the dykes, as low as was deemed safe, they could see that waves were reaching close to the crest, and that spray was continually being swept over. Due to the turbulence, landing was not possible, so they flew to where pickup trucks had been parked the previous day for the inspection team. On arriving at the dykes, the wind was so severe that it was almost impossible to stand on the crest. George was nearly thrown into the rip-rap as he opened the pickup door, and the wind flung it open. All they could do was observe and take some notes and photos of the situation. On returning to the helicopter, the pilot was asked if he could land on the dyke crest, and measure the wind speed. This was done, and a reading of 55km/h, with gusts to 65km/h was obtained.

Figure 1.

View from pickup truck of waves and spray washing over top of dike. It was not possible to stand on dyke crest due to force of wind. On opening the pickup door, it flew open and I was almost thrown into the rip-rap, so I climbed back in!

Figure 2.

Another view of waves washing onto dyke. Reservoir about 1.0m below full supply level.

The dykes and dams around the reservoir had been commissioned about 35 years previously, and had been designed to the highest standards. However, due to the very large number of dykes, it had not been possible to calculate the fetch, significant wave height, wave run-up and rip-rap size for every dyke. With the advent of computers, the inspection team had recommended a few years previously, a re-survey and computation of the required dam crest elevation and rip-rap size. This had been done, with 2 engineering students hired to check the crest elevation, rip-rap size and elevation, measure the level of the highest driftwood found in the rip-rap, determine the fetch from topographic maps, and take a panoramic video of the reservoir from the center of each dyke.

This data had then been entered into a spreadsheet designed to calculate the required dam crest elevation, and rip-rap size, and compare the actual and theoretical crest elevation and rip-rap size. The result was reassuring; with only a few dykes indicating that the crest was suspect. However, the dykes where spray was washing over, were shown to be suspect. With the data from the inspection, George used this to calculate the dyke crest level with the 55km/h wind speed, and also included data for reservoir level and set-up obtained from recording gauges around the reservoir. He then increased the wind speed to the design 105km/h, raised the reservoir by 0.9m to the full supply level, increased set-up in proportion to the square root of the wind speed, and obtained a crest level some 2m higher, a definite indication that the crest was too low.

On returning next day, to continue the inspection, there could not have been a greater contrast. The weather was clear and calm, with the blue water well below crest level, and George reflected that it would be impossible to imagine waves reaching crest level, nevertheless, he had the photographic evidence to prove it! The dyke crest level was increase by 1m, and a rip-rap berm was placed on the crest one meter higher.

Figure 3.

Next day – weather calm and sunny. It would have not been possible to imagine waves washing over the dyke!

Lesson learned.

Throughout the 35-year life of the project, there had been meticulous inspections of the dykes, and continual maintenance. There had never been any mention of significant spray washing over the dykes. However, the dykes were spread over a vast area, and were difficult to reach, except by helicopter. The furthest north dykes required some 3.5 hours travel over rough gravel roads, hence inspections during inclement weather were never attempted. Also, the vast multi-year reservoir only reached full supply level on rare occasions. Therefore it is not surprising that spray wash-overs were never reported. However, a 2m increase in crest height is very significant, and should have been detected during the design. A review of the design had been undertaken on several occasions, and was always found to be correct. If not the design, what about the methodology? This is where the story becomes murky. All wave height and run-up equations are based on measurements on a straight front, facing out into the ocean, with no islands. A reservoir is very different, with islands, and adjacent shorelines providing an opportunity for wave reflection. It is a well known fact that a V-shaped shoreline will enhance wave height by a significant amount, and attempts to use this phenomenon to generate water power at the head of fjords have been made in Norway, only to have the experimental powerplant destroyed by the proverbial giant wave after about 2 years operation. Based on these incidents, it would be prudent to review dam crest elevations where there is a large fetch, and the possibility of wave reflection from adjacent shorelines. Another clear indication of insufficient freeboard, is the level of driftwood and debris lodged in the rip-rap. If near the rip-rap crest, a review should be undertaken.

Figure 4.

Next year – adding one meter to height of dyke crest, plus one meter of rip-rap on top.

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