# Influence of measurement density in the flood risk assessment for piping

A theoretical analysis of the accuracy of strength assessments

Piping is a failure mechanism in which a concentrated water flow below a cohesive dike body causes erosion of soil particles. In periodic safety assessments, the probability of failure due to piping is calculated and compared with the legal norms. The possibility of piping is determined per by estimating what could be possibly the lowest strength present somewhere along a dike section. That representative strength is based on measurements from important soil properties. Because data is limited, it is uncertain if the estimated strength is equal to the actual strength. It would be unsafe if the estimated strength is higher than the actual strength because this can result in an unacceptable piping risk. Therefore, a number of conservative assumptions is made. Counterpart of this conservative approach is that dikes can be assessed as unsafe and need to be reinforced while actually meeting the norms. The hypothesis is that higher measurement densities helps to improve the strength assessment. In this research a theoretical analysis is made by modelling soil properties as random fields. Monte Carlo is used to analyse the accuracy of the strength assessment for uncertain soil conditions.

The resistance of a dike to piping is varying along the length as a consequence of varying soil properties. The cross section of a dike section with the lowest resistance is of interest for the piping risk and therefore defined as the reference strength. The assessed strength follows from characteristics value calculations based on uncertain measurement data. The error in a strength assessment is defined as the difference between reference and assessment. The magnitude of the error is dependent on the soil conditions. Because the soil conditions under a dike are uncertain, the error has a range of possible values. It is shown that this range of errors exist for every measurement density and can be decreased to some extent. The density till which the range can be decreased depends on the (unknown) variation pattern of the soil and the (unknown) measurement error. It is therefore not possible to conclude about an optimal measurement density without additional sources of information.

It is shown that the (unknown) variation pattern and measurement error determine the range of errors and the probability that an assessment underestimates or overestimates the actual strength. It is shown that for constant variation patterns the assessment is generally conservative as it intends to be. This means that it is not likely that the probability of failure is actually higher than calculated from the assessment. It is however likely that a dike is actually stronger than calculated. This can result in ineffective reinforcements. If it expected that a dike is much safer than calculated, an increasing measurement density can favour the assessment outcome. But the current assessment approach is not generally conservative. For some scenario's it is well possible that the actual strength is smaller than calculated. It is identified that sudden weak spots are easily overlooked by the current approach. Increasing the measurement density has not always the intended effect of preventing this danger.

It is concluded that the current strength assessment based on point measurements and characteristic parameter values is unreliable for every measurement density. With a couple of measurements and unknown soil variation patterns, the error in an assessment can in theory be up to almost 100%. It is also concluded that relative errors can still be up to 50% at high measurement densities. This is because some assumptions in the assessment are static, i.e. not influenced by the measurement density. An unreliable assessment can result in ineffective reinforcements or safety risks that are higher than accepted. It is recommended to study the possibility of (applying) volume covering measurements as it might provide necessarily information about variation patterns and identify possible weak spots.

*Figure 1: Example of a piping sensitive dike (https://beeldbank.rws.nl, Ron Boelens).*

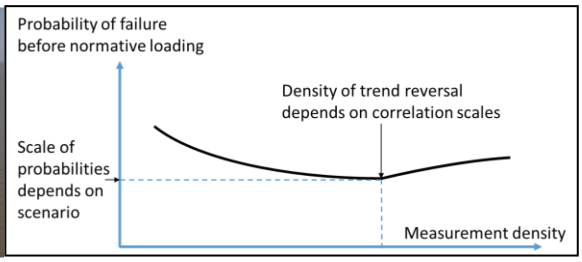


*Figure 2: The relative influence of measurement density to the probability that a dike is weaker than estimated in the assessment.*

**Julius van Stokkum**

**Graduation Date:**
1 July 2016

**Graduation committee:**
*University of Twente*
Dr. J.J. Warmink
Dr. K.M. Wijnberg

*BZ Innovatiemanagement B.V.*
ing. W.S. Zomer MSc

UNIVERSITY OF TWENTE.