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# Living Lab Hedwige-Prosperpolder, a playground for training skills regarding emergency response

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**Abstract:**
The realisation of managed realignment of the Hedwige-Prosperpolder at the Dutch/Belgian-border offered a unique opportunity to learn more about the strength of real dikes under simulated extreme conditions as well as to exercise with state-of-the-art emergency response tools and techniques. In this paper are presented on one hand the numerous destructive tests that have been executed on levee sections with presence of animal burrows, cliffs, trees, vegetation and on the other hand the organisation for emergency response in practice.

**Keywords:**
Coastal engineering, Levee, Wave, Overtopping, Overflow, Erosion, Emergency response, Inspection, Breach, Risk.

## 1. Introduction

Climate change is affecting countries like Netherlands, Belgium, France and UK faster and to a greater extent than previously expected. The rising sea level is a serious threat to these countries. Especially, since it is not known exactly how strong the flood defences are and how well emergency response is organised in practice. Also, there is a shortage of well-trained water managers and a lack of embedded knowledge transfer and societal awareness.

The realisation of managed realignment (a.k.a. depoldering) of the Hedwige-Prosperpolder at the Dutch/Belgian-border offered the unique opportunity to learn more about the strength of real dikes under simulated extreme conditions as well as to exercise with state-of-the-art emergency response tools and techniques. Living Lab Hedwige-Prosperpolder (Living Lab HPP) was born.

The INTERREG 2 Seas project POLDER2C's combined research, practice and education in a unique way. In both winters of 2020-2021 and 2021-2022, the Polder2C's project ran real life destructive tests on levees within LL HPP and provided engineers the opportunity to study the actual strength of real levees. Levee inspection exercises were carried out. Emergency measures were deployed. Special attention went to formalise knowledge transfer and educate the next generation of water managers.

## 2. Simulating superstorms to test erosion resistance

Numerous destructive tests have been executed on levee sections with presence of animal burrows, presence of (animal-induced/artificial) cliffs, trees, vegetation indicating wet conditions, etc. (see figure 1).

*Figure 1. Anomalies being tested under extreme loading conditions: animal burrows (left), (animal-induced) cliffs (right).*

In some cases, arising damage was repaired (see further) and these emergency measures were solicited again with continuous overflow or overtopping waves (see figure 2).


*Figure 2. Repairing damage using Cocos mat, Tyvek, EPDM and reinforced turf mat.*

For these experiments, various impressive machines were used, such as a continuous overflow generator (VERCRUYSSE *et al.*, 2022), a wave overtopping simulator and a wave impact generator (see figure 3). Trials confirmed the good erosion resistance of grass revetment in overflow, under wave overtopping or under wave impact.

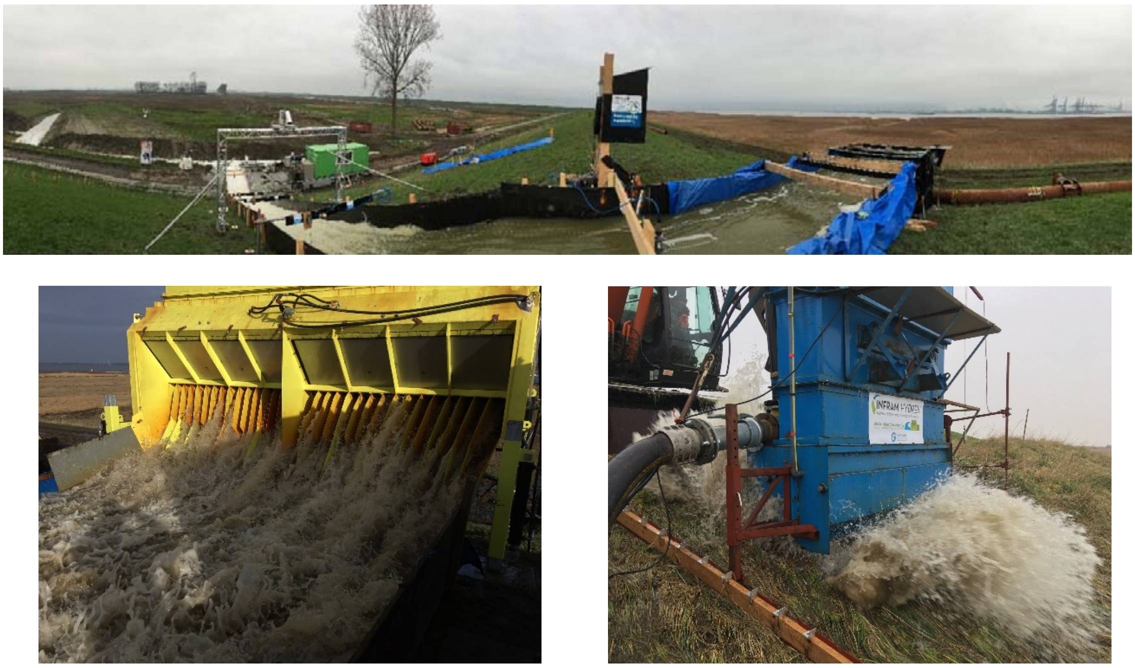

*Figure 3. Overflow generator (top), Wave overtopping simulator (left), Wave impact generator (right).*

During the tests, hydraulic loading conditions as well as the actual state of the cover layer were monitored through the use of fixed flow discharge, water level and velocity sensors, of cameras on portals for top view of the test section, of high-speed camera's for visualisation of flow patterns, of (handheld) LIDAR devices for measuring changes in water surface and slope profile, RTK GPS for georeferencing (see figure 4).

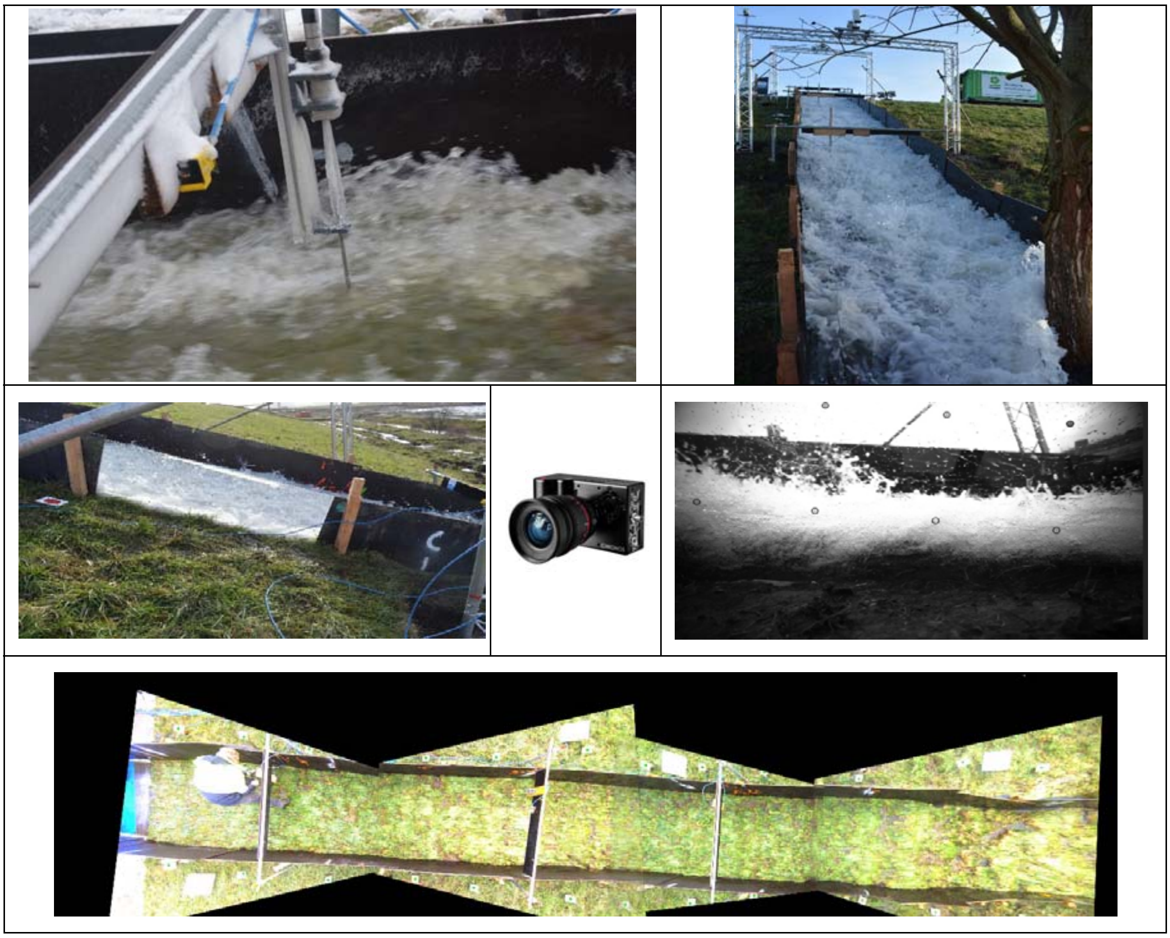

*Figure 4. Deployed measurement devices and outcomes: Fixed water velocity and water level sensors (top), Use of high-speed cameras (middle), Damage image from fixed camera with top-view (below).*

In addition, portable devices were deployed for assessing erosion resistance, such as the Jet Erosion Test (JET), the Grass Sod Pulling Instrument and the Fire Hose Method (see figure 5).

*Figure 5. Sampling for JET-experiments (left), Grass Sod Pull test (middle), Fire Hose test (right).*

**3. Training skills for emergency response**

An important goal of this project was to improve our knowledge of how we organise our emergency response in practice.

3.1 State of play

Maturity models can be used to assess capability levels, offering the partners a method to assist them in improving their performance and maturity. We distinguish five maturity levels, from ad hoc to optimize. By determining current capabilities and performance, while simultaneously identifying areas of weaknesses, potential learning objectives can be indicated. A maturity analysis enabled the project partners to assess their own performance from 1, meaning ad hoc, to 5, meaning optimized, on various indicators: adaptability of new technologies/procedures, knowledge exchange, data information management, accessibility of skills and tools, crisis and risk communication, crisis and risk emergency resources, (inter)national collaboration, and resilience. The initial State of Play started off with a survey, followed by individual meetings to further discuss maturity levels and potential learning objectives. The results of the initial State of Play are shown in figure 6. This exercise can be replicated at the end of the project in 2023.

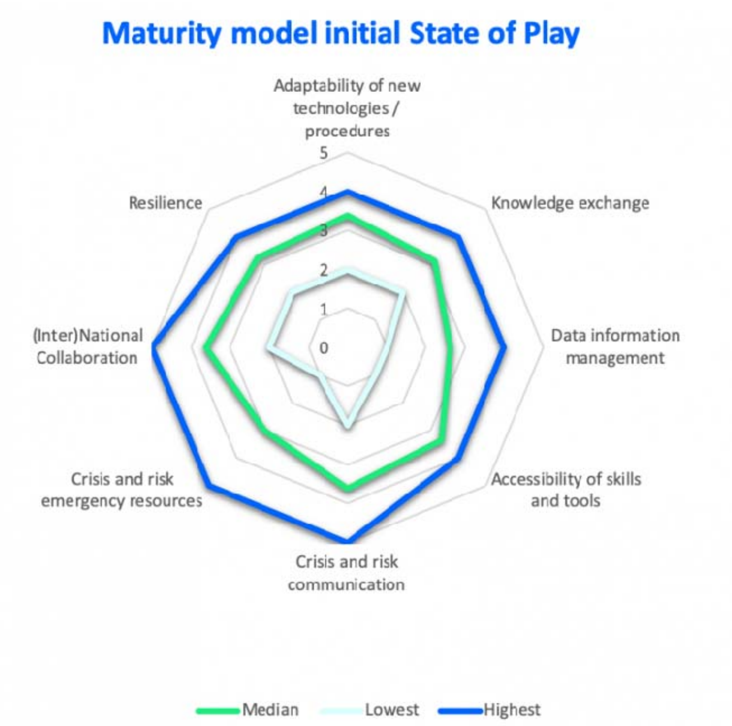


*Figure 6. Maturity model initial state of play.*

3.2 <u>Inspection exercises</u>

The emergency response exercises were implemented for five main damages: local crest lowering, erosion holes or fallen trees, sand boils caused by piping, cracks due to slope instability and animal burrowing (fox holes). The Plan-Do-Check-Act, PDCA circle, started with observing and finding of damages during an inspection, making use of the newly-developed inspection app2C on smartphone. The levee app (see figure 7) was developed by ESRI to organize observing and inspection of levees for non-expert levee inspectors. The app enables levee guards to report damages, including the damage location, size and photos. Next, we focused on diagnosing and prognosis of the right approach, eventually leading to the execution of needed emergency measures. With the execution of emergency measures, we started observing again, closing the PDCA circle.

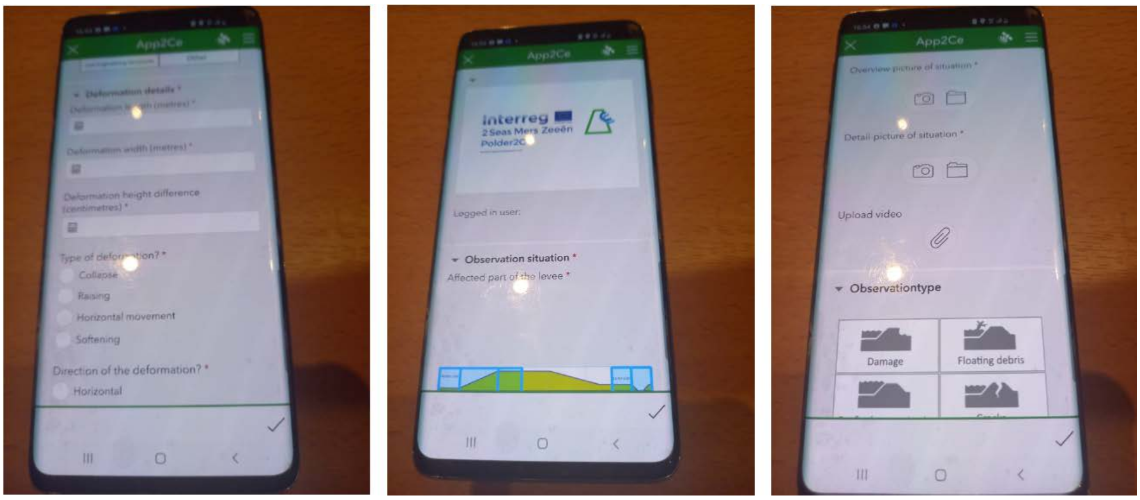


*Figure 7. Newly-developed inspection app2C on smartphone.*

Advanced observation techniques were proposed in order to improve inspection methods.

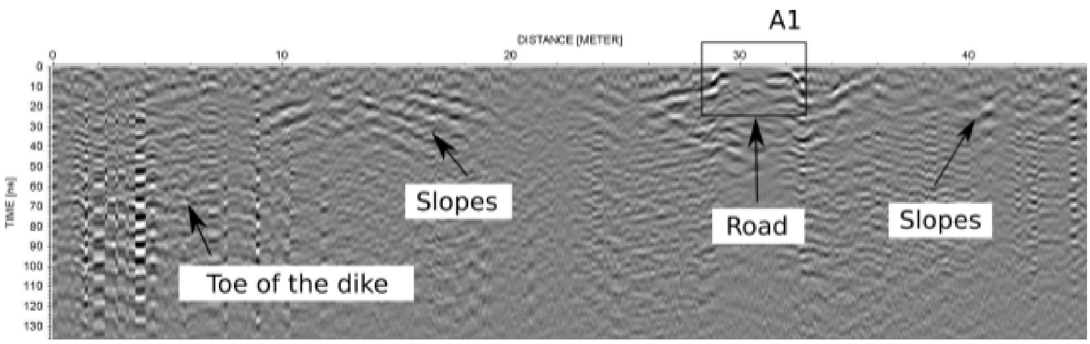


*Figure 8. Radargram displayed without topography. The A1 label refers to signal associated to the road.*

The GPR for example allows to image the subsurface through the analysis of electromagnetic (EM) waves reflected/diffracted by dielectric contrasts encountered by EM waves into the soil. A ground coupled bow-tie antenna of 200 MHz has been used to record GPR profiles (ANTOINE *et al.*, 2021). Each profile was located using a GNSS device. Classical data GPR processing was performed thanks to the ©ReflexW software, including static correction, low-pass filtering gain function and background removal. The maximum depth of investigation was ≈ 5-6 m. An example of radargram carried out along the T10 profile is shown in figure 8 without topographic correction. The principal reflectors can be observed and linked to the different parts of the levee.

3.3 Emergency response exercises

*Figure 9. Emergency response to repair the outer slope of a damaged grass covered levee.*

Groups of students were asked to repair the outer slope of a damaged grass covered levee in the Hedwige-Prosperpolder as well and efficiently as possible with their own innovative and durable protection measures. The temporary reparation of the levee (before later a permanent reparation) needed to be sufficient to withstand a series of wave overtopping generated with the wave overtopping simulator. The proposed emergency response in figure 9 required the use of geotextile and sandbags. For the very first-time rock bags were also used to repair levee damage in the Living Lab Hedwige-Prosperpolder.

3.4 Breach closure strategies

If a levee breaches, accidentally or deliberately, it has to be closed as fast as possible. We explored different breach closure strategies under different circumstances, such as wide or small breach, high or low water velocity, accessible from land, water or air. We tested proven and innovative solutions such as a BreachDefender and mobile barriers.

The BreachDefender (see figure 10) is a multifunctional military pontoon folding bridge being developed and tested by the Dutch Ministry of Defense. It can be used to stop or postpone the initial breaching process of a levee.

*Figure 10. Multifunctional military pontoon BreachDefender.*

Another breach closure strategy consists in using mobile barriers. In February 2022 four types of mobile barriers were tested: Boxbarrier, NoFloods Flex wall, Mobieledijken (mobile levee) and Cuirassier (see figure 11).

*Figure 11. Testing mobile barrier of Cuirassier in Hedwige-Prosperpolder.*

The tests were used to verify the main design criteria for the mobile barriers, namely the leakage rate, the mechanical stability to the water column and to the wind under different soil conditions, the possibility of laying with curvature or slope and finally the setup time.

3.5 Controlled breach initiation
Controlled breaching of a levee may be used to release the overall pressure on a levee system and prevent uncontrolled breaching. A possible initiating way is through the use of explosives. Water authorities and Dutch Ministry of Defence determined controlled breach initiation in a situation of high-water levels.

3.6 Risk perception study
A flood risk perception study was performed among citizens living in the area close to the Hedwige-Prosperpolder. The research focused on citizens' attitudes towards evacuation, their information seeking behavior and behavioral intentions in case of imminent flooding. The Hedwige-Prosperpolder provided a unique opportunity because risk perception studies are generally performed in the context of imaginary, hypothetical flood scenarios.

## 4. Conclusions

Impressive machines were used in Polder2C's project, such as a continuous overflow generator, a wave overtopping simulator and a wave impact generator. Tests have been used in order to improve the knowledge of the physical processes at the real scale of the levee of Hedwidge-ProsperPolder at the border of Belgium and Netherlands and to set up robust numerical models predicting future erosions of coastal levees.
Practice of emergency response around coastal levees was even more original. Partners of the four countries (Belgium, France, Netherlands and United Kingdom) have been involved in inspection exercises and emergency exercises in Hedwidge-ProsperPolder with geotextile, sand bags and rock bags. Showcases of innovative techniques have been organised like the use of a newly-developed inspection app2C on smartphone, drones or radars for monitoring as well as BreachDefender and mobile barriers for breach closure. Replication of these exercises is in discussion with Bay of Somme in France with attention paid to specificities of French sites like the presence of rural zones for example.

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