Robust monitoring

- 2009.02.02.1 Visualisation of levee quality based on sensor data

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Document Management

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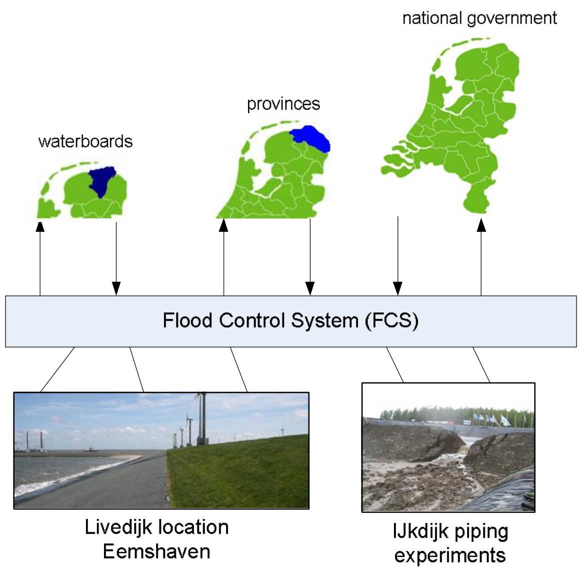
Management summary

This deliverable with title "visualisation of levee quality based on sensor data" describes a vision on a Flood control system, the requirements for such a system and several visualisation forms.

Within several years it is most likely that more levees are equipped with some kind of sensor system. Every Dike manager will have it's own preference for a certain system or measurement technique suitable for their specific local situation. The consequence is that there will appear a lot of different *Dike Monitoring Systems* monitoring a specific levee section. An entire overview on dike ring level, waterboard level or national levels l not be possible due to the very different Dike Monitoring system.

A *Flood Control System (FCS)* will integrate all different dike monitoring systems and provides added functionality. A Flood control system has the following high-level characteristics:

- sensor data from sensor systems is available for connected parties
- knowledge providers (e.g. model experts) are able add their knowledge to sensor data and publish the result in the FCS
- connect parties are able to share their domain knowledge
- a FCS makes information suitable for different aggregation levels
- a FCS keeps providing information even if parts of the infrastructure fails, the information will be based on different, possible indirect, sources.
- a FCS supports processes for operational – and crisis situations



Simplified overview of a FCS: sensor data becomes sensor information that is suitable for multiple stakeholders in the water management chain.

The project Robust Monitoring also build a demonstrators of the envisioned Flood control system and connected serveral sensor systems from the IJkdijk experiments en Livedike location ath the Eemshaven (Delfzijl).

1 Introduction

This document is mainly divided in three main connected subjects. The first part (chapter 2) outlines a vision on a Flood Control System across organisations boundaries with multiple organisations involved. This part outlines an envisioned system approach for an integral Flood Control System on top of a variety of dike monitoring systems which will be implemented by water boards in the near future. The supporting architecture design to implement a Flood Control System is not described in this deliverable but in the “2009.02.01.2 Architectuur en prototype dijk monitoring system” deliverable.

The second part (chapter 3 and 4) of this document describes an analysis of the Dutch water management situation and defines two scenarios as a basis for requirements gathering for a Flood Control system.

The Thirds (from chapter 5) part of this document describes different views on sensor data for the different stakeholders involved in water management. For different roles in water management a few specific visualisations are designed and implemented.

The deliverable for this activity (2009.02.02.1) is not only this document but also consists of several software components that where developed during the project:

- implementation of the Dike Manager role in IBM’s asset management application Maximo
- implementation of a generic visualisation for different roles in Adobe Flex technologie
- both visualisations connect to the flood control system in order to get sensor data

1.1 Approach

The goal of this document is to define the visualisation (user interface) of the Flood Control System prototype. In order to keep the prototype aligned with business goals the Eclipse Open Unified Process [elc] to describe the approach.

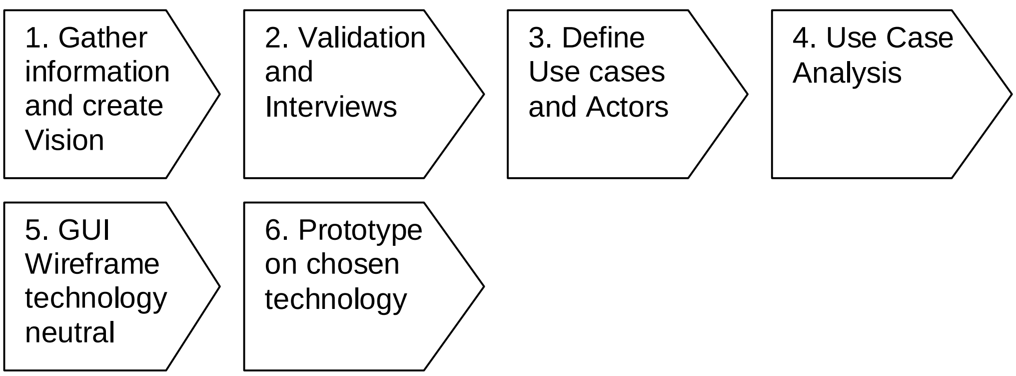


Figure 1-1 The process followed to create prototype (based on the Eclipse Open Unified Process)

A description of the 6 steps:

1) Gather information and create vision about the intended innovative solution.
   People and other information sources are studied to understand the Flood Control Domain, capture 'domain terminology' and innovation opportunities. Brainstorm sessions will identify additional innovations. Based on this information the vision for the Flood Control System is written and validated.

2) Validation and Interviews
   People working in the field of levee inspections and Flood Control will be interviewed to validate the vision to make sure the developed prototype is aligned with business goals.

3) Capture the use cases (scenarios) and actors.
   Based on the interviews use cases (scenarios) are defined. These provide a clear understanding of the situation that the prototype will be used in and clearly identifies the involved actors.

4) Use Case analysis
   Because the use cases do not include details about the information used in the outlined process, an information analysis step needs to be executed. Extra interviews with end users might be needed to identify the most important information items.

5) GUI Wireframe, technology neutral
   Based on the analysis of the use cases a user interface (GUI) wireframe will be created. This outlines the generic view on the use cases and is independent of technology. It will be used as inspiration and reference for designing user interfaces on other technologies that might provide constraints on user interface design. It's purpose is to provide a clean view of the envisioned solution without being tied to the constraints of specific technology.
   Industry GUI design reference models will be used to align the user interface with industry standards.

6) Prototype on chosen technology
   Based on functional criteria from the use cases and other relevant criteria (e.g. technical, financial, etc.) the products and technologies are chosen to implement the prototype. The GUI Wireframe will form the inspiration for user interface design. As products have their own constraints on the configurability of the user interface it will often be different from the wireframe. In this step those constraints are taken into account to do actual user interface design for the prototype.

The method used for designing the user interface is the User-Centred Design process [ibm01]. User-Centered Design (UCD) is an accepted industry approach for designing applications that are highly usable by their end users.

For more information regarding the User-Centred Design process reference is given to the appendices.

1.1.1 Alignment with the solution architecture

The architecture and prototype design document (“2009.02.01.2 Architectuur en prototype dijk monitoring systeem).doc” describes the technical implementation of the system, the so called Application Architecture and the Infrastructure Architecture.
The architecture levels that can be distinguished are:

- Business architecture
  - Who are the key people/organizations that will work with this system? These are the primary actors of the system.
  - What will they do? This is described in the high level key use cases.
  - Which information is needed? This is described in the information model.
- Application architecture
  - What are relevant reference models ? This results in specific user interface design requirements.
  - How can the user interact with the system ? This is worked out in a hi-fi prototype (wireframe)
  - How should the physical application look like ? This is described in the user interface style guide and the user interface specifications. Resulting in the final built of the application.
- Infrastructure architecture
  - What hardware will the prototype run on?~
  - How will the software be configured.

As the table below indicates. This visualisation document describes:

1) the business architecture
   It describes the vision and the way the prototype will be used (use cases) as well the information that is processed.
2) A part of the application architecture
   The user interface design is part of the application architecture but will be described in this document to have a logical grouping.

	Aspect	Concept	Logical	Physical
Business Architecture	**Actors**	N/a	Information analysis - Actors	RM Demonstrator
	Use Case	N/a	Information Analysis - UCs	RM Demonstrator
	Information	N/a	Information analysis - ERD	RM Demonstrator
Application Architecture	**Function**	Reference Architectures - SOA / NORA	Application Architecture	RM Demonstrator
	User Interface	HCI Reference Models	Wireframe	UI Style guide UI Specifications RM Demonstrator
Infra Architecture	**Availability**			
	Performance			

Figure 1-2: Information analysis and user interface design related to architecture levels

2 Vision on smart levees

This chapter outlines the vision of a Flood Control System in the year 2015 for smarter levee maintenance and operation use in crisis situation.
It will start to introduce the driving force behind the need to increase safety standards and therefore improved levee maintenance and crisis decision support based on real-time factual information.

2.1 Introduction of the driving forces and trends

Levee quality standards are very high in the Netherlands. Levees have been design to withstand risks of 1:1250 years for rural areas to 1:1000 years in the coastal populated regions. Although levee breaching and flooding is very rare in the Netherlands a couple of accidents (e.g. Wilnes and Stein) have pointed out that the internal strength of the levees is unknown and that there is greater potential of flooding than was expected. The lack of information on levee status was also pointed out by the primary water barrier safety validation of 2006. That study showed that only 45% of the levees/barriers are up to design standards. The status of 55% of the levee system is unknown or insufficient [baa09]

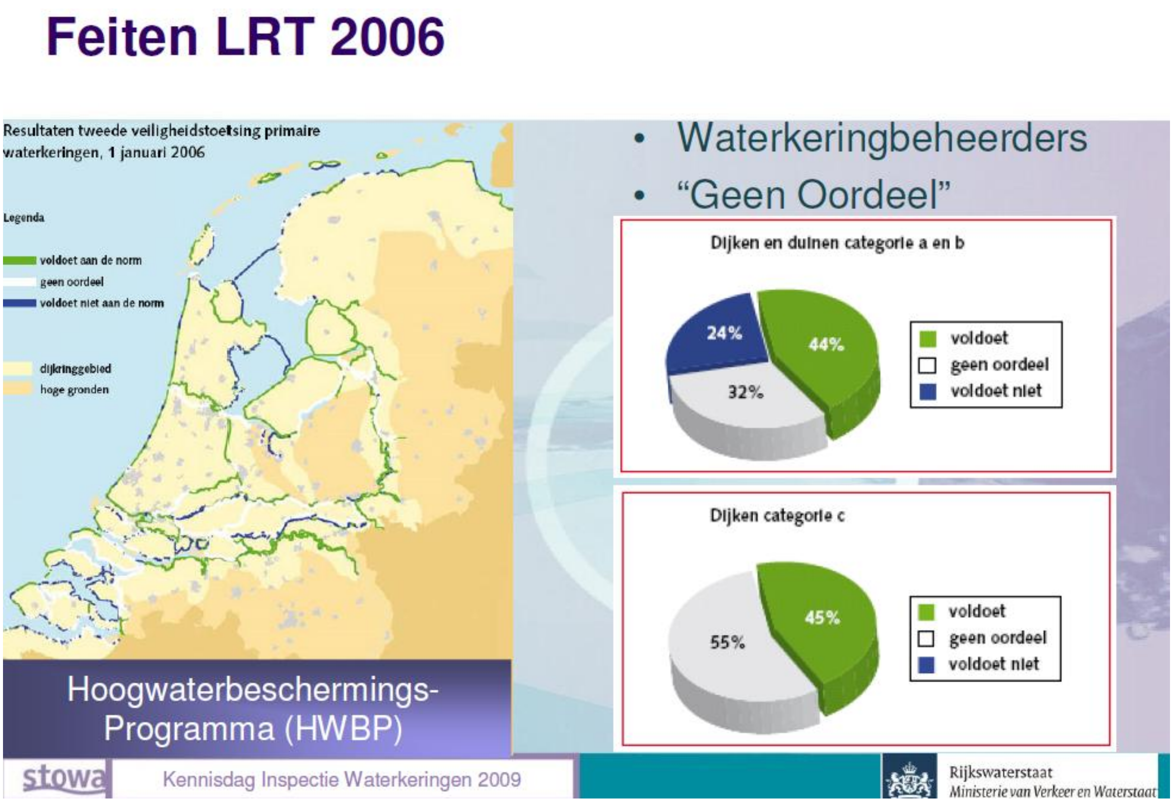


Figure 2-1 Results of security study of primairy water barriers in 2006 (source: STOWA kennisdag 2009)

The same figures are present in the recent report Waterschapspeil 2009 of the Union of water board [uvw1].

Based on these findings and the rising threat of climate change, the Dutch government decide to re-examine the risks of flooding. The Delta Commission that executed this study advised the government in 2008 to improve this risk ration to even higher standards of 1 on 10.000 years (http://www.deltacommissie.com/).

Conventional methods and techniques (making levees higher and wider) to reach these new design standards are mostly inadequate and overall extremely costly. New innovative methods are needed. Rethinking, finding a smarter way of reaching the new design standard, of levee construction, maintenance and flood control is needed. This is what the Smart Levee in its broadest sense is about. The goal of a Smart Levee is to improve safety and protection of investments at a more efficient and cost effective way. Better, more precise and real-time factual information is seen to be a key contributor to the Smart Levee. The upcoming trend of instrumenting our planet with sensors to provide more fact based information at the right time is part of this vision and what this project will focus on.

During the last few years, the real-time measurements with sensors of all kinds of parameters in levees have gained attention. The technology of sensors for levee monitoring is in rapidly improving and the stability of levees will be increasingly monitored as an addition to the visual inspections. The combined information from visual inspections and sensor systems is relevant for a number of organisations which are concerned with safety with regard to water.

2.2 Vision on a Flood Control System

In 2015 many dike managers (water boards, Rijkswaterstaat) will use dike monitoring systems of all kinds to monitor the stability of levees. Different techniques of various vendors will be in use (remote sensing, in-situ sensors for movement, pressure, etc.). These monitoring systems are optimized to monitor a specific levee section in detail (for instance a peat levees section or dunes) to help in maintenance decisions and during crisis situations. In addition to this detailed view, dike managers need a consistent view of the levee system as a whole. This will help them consistently report about the levee system, compare levees status and share knowledge with other dike managers and to improve maintenance processes to decrease costs and improve quality. Beyond the dike manager other actors are using levee information in their business, for example to decide on safe land use for housing or economic activities.

A Flood Control System combines the information from various specific Dike Monitoring Systems and enables the sharing of this information over organisational boundaries.

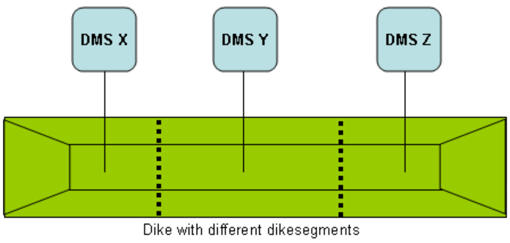


Figure 2-2 Different dike of dike segments are monitored by different dike monitoring system, an overall view is not possible

Various organisations will increasingly use the combined information in their processes, as also defined in the EU Flood Directive. For example: a dike manager is responsible for levee maintenance and might create a report on the levee stability by combining levee sensor information with visual inspection reports. This levee stability can be re-used by the province that adds population information to it to report on safety for the public of specific regions in the province.

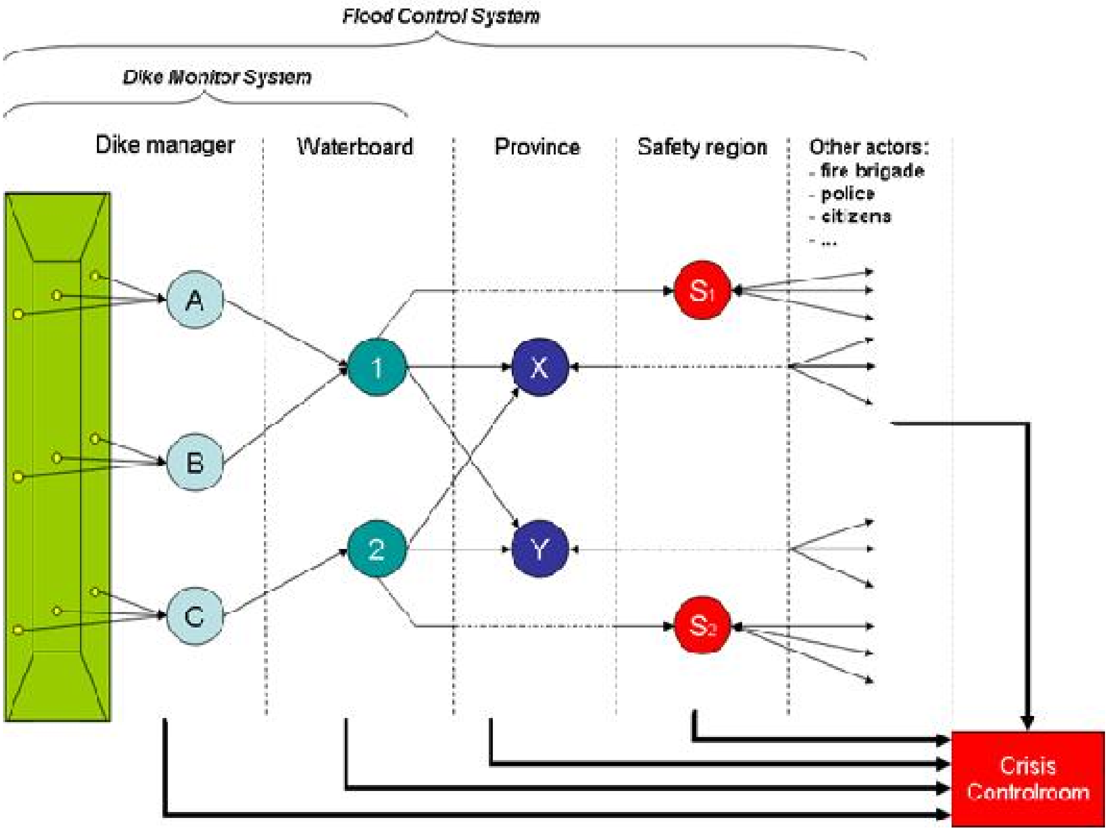


Figure 2-3 Scope of a Flood Control System

The information will be available to everybody at any time, this is called Network Centric Operations – a concept created by the military and described by John Boyd in the OODA loop [boy].

This concept is especially useful in crisis situation to create a ‘Common Operational Picture’ of the situation to every actor in flood emergency situations. This means that any actor in the crisis process has access to the same information at anytime. This is in contrast to procedure based crisis handling in which information will only be distributed to selected actors according to pre-defined crisis procedures. As a crisis never follows the same pattern this procedure based approach is not optimal: actors will often only receive partial, already interpreted information too late because and not directly when this information was available from the source.
As highlighted in the figure above the information will also be available in the Crisis Control room, which is covered in the Flood Control 2015 project “Demonstrator Flood Control Room”. The Robust Monitoring project will adhere to the standards and architecture laid out in that project so that it nicely integrates.

When information, like the levee stability report, is contributed back for other to re-use you can view this information as if it were a new (synthesized) sensor. We will call this the ‘Virtual Sensor’. When various organisations make use of each others Virtual Sensors the information gets enriched with every step. We call the creation of a new Virtual Sensor based on the re-use of other Virtual Sensors ‘Information Chaining’.

Because a Flood Control System spans multiple technologies (Dike Monitoring Systems) and organisational boundaries it is important to address the robustness of the system. Even if one Dike Monitoring System, or some sensors of that system, will fail, the system has to continue to be useful. A detailed examination of the definition of robustness is detailed in §2.5.
For a Flood Control System to be successful it has to be used in regular processes as well as in crisis processes. If it were only used during crisis processes than people would not be able to operate it due to the lack of routine. Therefore, and for economic reasons the Robust Monitoring Demonstrator build in this project will show its usage during regular (daily) processes and in crisis situations.

2.3 Timelines in sensor data

The collection of correct and clean sensor measurements from the different Dike Monitoring Systems can be troublesome. The calibration of sensors can become off, sensor measurements may need to be corrected to be easily used, external events which polluted the measurements need adaptations to the measurements etc.

The difficulties with collecting sensor data do not mean that the original (off) measurements should be deleted. They can always be needed if corrections happened to be false, or for different purposes different corrections are needed. We would like to have a mechanism which binds all these changes together and still is able to access the original measurements.

It would also be nice if there would be a relation with predicted measurements. These predictions are nothing more than (expected) measurements in the future. They follow each other in a natural manner. Of course a model to calculate these predictions is needed and furthermore these models should support streaming, e.g. calculate predictions on-the-fly. If such a model exists, it would make sense to store these predicted measurements in a similar manner as real measurements and relate them to each other. The answer to all these wishes is to use the concept of timeline to store sensor measurements.

The timeline mechanism gives us an efficient, reliable and easily accessible manner to store and retrieve different appearances of sensor measurements.

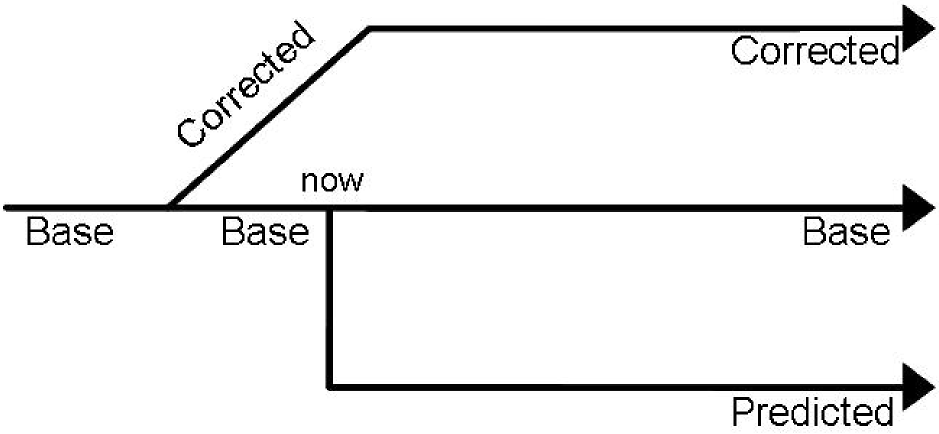


Figure 2-4: the base sensor stream is branched in different timelines while the orginal measurement still is available

Consider the need for a correction on the measurements, for instance the sensor produces logarithm based values and a linear version is desired. Instead of calculating the linear value and only storing that one, a new timeline is created. This timeline, which can be named “corrected-timeline”, is related to the base timeline. This indicates that the measurements in the corrected-timeline are based on the measurements in the base-timeline.

2.4 Perspectives of a Flood Control System

As described above, a Flood Control System combines Dike Monitoring Systems, forecasting models information from other sources (e.g. population, economic density) to support decision making to take the right responsive action. For example, by combining all this information a Flood Control System can produce a real-time overview of the region: flood maps, escape routes, predicted damage to property and time to evacuate. This will be used to support coordination of responsive actions.

To fully understand the scope of a Flood Control System it needs to be viewed from different perspectives (e.g. organisational structure, the processes it supports, the technical perspective). A good way to do this is to use an enterprise architecture model. A simple model that provides five distinct perspective of the system is shown below followed by a description of each perspective. Each perspective is aligned with the perspective above so that a coherent system is created that is driving by the vision as outlined above.

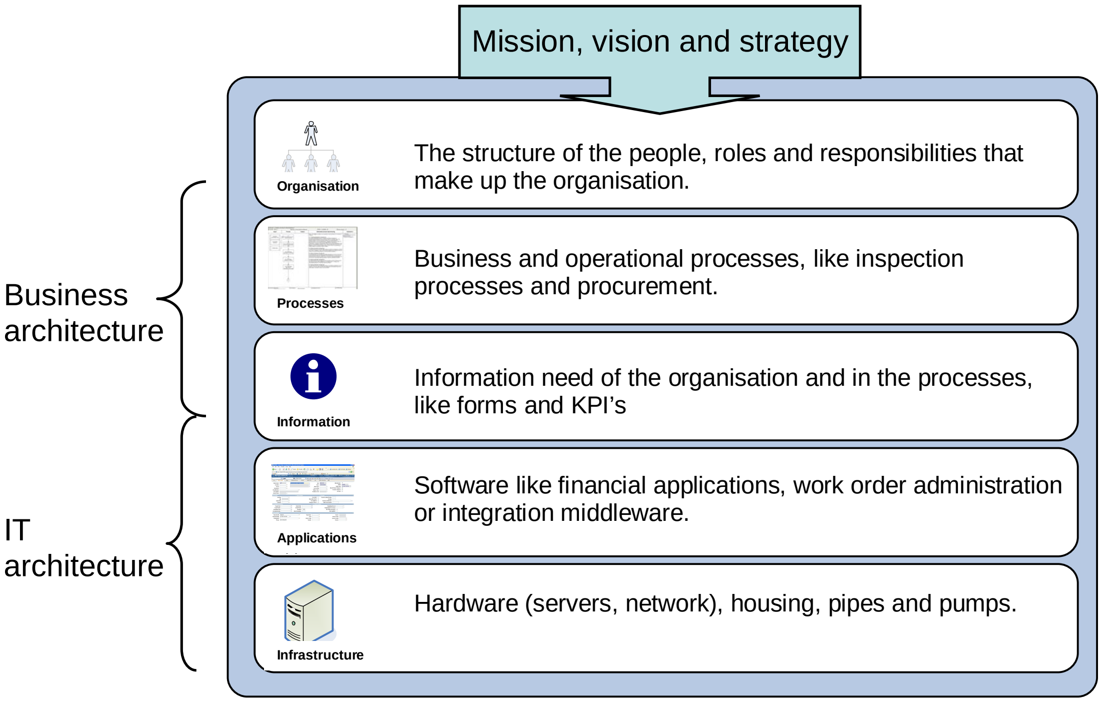


Figure 2-5: High level architecture model showing the different perspectives of a Flood Control System (source: Gemeente Amsterdam)

2.4.1 Organisational perspective

This perspective describes the organisational structure for Flood Control.
Flood Control is a combination of two domains: the Water Management domain for prevention and maintenance based organisations and the Disaster Management domain for crisis management in which emergency services are present.

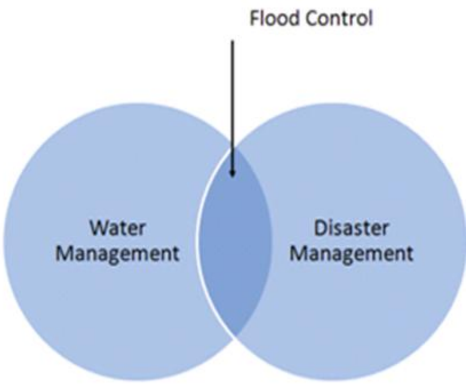


Figure 2-6 Flood Control domain

It includes the stakeholders, such as the owner, dike manager, inspectors, maintenance staff or various administrative functions, but also local governments and emergency services.

The organisation construction of the Flood Control domain has been described by Diana Mongula in her thesis "Enterprise Ontology for the Flood Control Domain" [mon09]. This will be used as basis for the Flood Control System.

2.4.2 Process perspective

Describes the crisis and maintenance processes as defined in the organisations that will use the Flood Control System. It includes all processes during the safety chain approach, from pro-action to recovery.

Figure 2-7 Safety Chain approach

Diana Mongula [mon09] has also described all processes in the Flood Control domain in her thesis on which the Flood Control System is based.

2.4.3 Information perspective

To enable advanced water management the combination of information is critical. In this perspective, the Flood Control System is a platform through which all relevant information is available. Each actor has access to all data and can create their personalized view and deliver there view/knowledge back to others. Hence from the information perspective there are different levels of abstraction viewed from the different perspectives of the actors and stakeholders.

2.4.4 Application perspective

Each organization will use different systems and application to automate their processes. The Flood Control System will enable all these systems to reuse the information through open standards. The Flood Control System is not one monolithic application, but geared towards sharing and integration of various systems.

2.4.5 Infrastructure and physical perspective

This perspective describes the dike and its surroundings, the actual sensors, sluices, pumps, actuators, their connectors and network infrastructure. The Open Geospatial Consortium gives a good overview of different sensor- and monitoring systems which are all connected to some kind of computer accessible network, e.g. the internet.

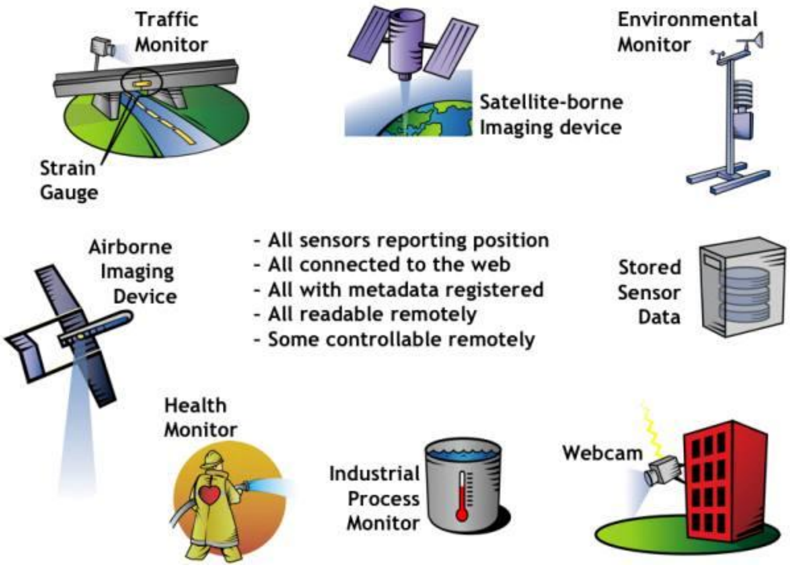


Figure 2-8: In a sensor web, different types and sources of information are linked. This is called Sensor Web Enablement (Source: Open Geospatial Consortium).

Different sources of information in a sensor web are shown in Figure 2-8. Another source of information is formed by ad hoc sensors, e.g. a mobile phone of a citizen. During a crisis, the crisis team will use various types of information (e.g. from police, fire department, internet, news, etc). From the combination of the three figures it is clear that an organisation can be both a user and a supplier of data.

2.5 Robustness

This project is about robust monitoring, the question rises then what is robustness? There are many definitions, in Wikipedia Robustness is defined as:

“Robustness is the quality of being able to withstand stresses, pressures, or changes in procedure or circumstance. A system, organism or design may be said to be "robust" if it is capable of coping well with variations (sometimes unpredictable variations) in its operating environment with minimal damage, alteration or loss of functionality.”

Although the definition should be red as one, special attention should go to the phrases *coping well* and *variations in its operating environment*. Coping well means be able to fulfil your goals as long as possible. Variations in its operating environment is about being aware of the operating environment and be able to deal with variations in it.

In case of flood control, coping well means: be able to avoid flooding and if that is no longer possible, control the flooding for as long as possible. In other words, robustness in a normal, non-flooding situation could be different from robustness during a crisis, during real flooding. Robustness is not about the black and white between if something is working or not. Robustness is about if the system is still be able to fulfil its goal in an useful manner. In case of a crisis also less reliable data becomes useful, because often that is all the information available. As long as the crisis team knows how trustworthy that information is, it can be useful.

An important part of the flood control system is the monitoring of the dikes, the monitoring of the stability of the dikes. Robust monitoring is the focus of this project. This results in the following focus on robustness during normal and crisis situations:

- Robustness in a normal situation means: to be able to reliably inform and prediction about the stability of the dike

- Robustness in a crisis situation means: for as long as possible to be able to predict the stability of the dike with an indication of the reliability of this prediction.

2.5.1 Goals of robustness

There are many aspects to control in order to make a system robust. Each perspective, as described in paragraph 2.3, should be robust. A robust system should be able to withstand all kind of problems, which can come and go over *a long period of time*. The following list shows a number of them, by no means is this list complete!

IT architecture

- Physical sensor infrastructure
  - Can withstand the weather influences: water, wind, etc.
  - Can withstand the environmental situation: salt, different soils, etc.
  - Can withstand small movements of the ground in order to monitor the first indications of dike failure without breaking the system.
  - Can withstand broken connections (cables, connectors, etc.) without the system as a whole going down.
- IT infrastructure
  - Can withstand all kind of hardware failures.
  - Can withstand all kind of software failures
  - Can withstand complete failure of a data centre. Something not uncommon in case of flooding.

Business architecture

- Informational
  - Can withstand faulty sensor data. Due to sensor calibration shifts (ageing) failing sensors.
  - Can withstand absent sensor data. Due to sensors breaking down, being stolen, drifting away on flood water.
  - Can withstand differences in analyses and/or prediction by models.
  - Can withstand differences in analyses and/or prediction by organisations.
- Organisational
  - Can withstand less optimal functioning of the organisations due to flooding failures in their systems.
  - Can withstand the absence of certain roles/functions (due to flooding failures). The building of the dike manager has been flooded.

2.5.1.1 Physical sensor infrastructure

The physical infrastructure has a huge influence on the robustness of a flood control system. Beside the condition of the dikes themselves (which are outside the scope of this project) the physical sensor infrastructure are a critical component. Dikes are there to last almost forever, it is very normal for a dike to be a 100 years old.
The flood control system uses sensors to get an up-to-date view on the situation of the dike. Sensor infrastructures are far and far less durable than dikes so far. There are not many sensor systems older than 25 years, even 10 years. Electronic components are not designed to last 100 of years, the weather is harsh, salt in the oceans are oxidising the cables and electronics, etc. Designing a robust physical infrastructure is a difficult task which needs a lot of research and maintenance planning to meet the safety requirements stated to “non sensored” dikes.
This topic lies out side the scope of this project.

2.5.1.2 IT infrastructure

Flood control systems, as being developed in this project, rely heavily on computers and software, on the IT infrastructure. This IT infrastructure must have a high availability, a high robustness, because it is a key component of the system. Software may not crash or cease to operate, especially during a crisis. Therefore al lot of attention should take place in developing a robust IT infrastructure. For the IT industry, this is not an uncommon question and techniques to provide such a robust IT infrastructure are available. Therefore this topic is not further investigated in this project.

2.5.1.3 Business architecture

In this project the focus is on how to make the business architecture robust. In order to know how to do that, the next paragraph first focuses on how to make things robust.

2.5.2 Making the business architecture robust

Making things robust is a difficult task, because you never know which problems/failures the system will run into. The solution is to design the system in such a way that it keeps operation, for as long as possible, when things break down. Instead of being able to implement dedicated solutions for certain problems. As soon as such solutions are available they should be implement of course, but they can not be designed before the problem is known.

There are three major approaches to keep the system working after things break down, which are important in case of a flood control system:

- Use more than the minimal needed number of things (sensors, models, people, etc) in order to be robust against failures of a few of them.

- Use different approaches to find answers to important questions and correlate them. The moistness of a dike can be determined in different manners: water pressure sensors, temperature decrease, etc.

- Be able to work with *grey* data/information, the area between perfect operation and total failure. By knowing the quality, the reliability of the data, a better decision can be made to use the data or not. This way useful data can be used a lot longer.

Applying these approaches to the robustness goals of a flood control system results in an increase of the robustness of the system. Especially a flood control system interacts heavily with the environment; it monitors the condition of the dikes, the weather, etc. It observes the environment, it orients on the effects, it decides what to do and lastly it will induce acting on these decisions. Acting can be sometimes automatic (opening of a valve) or done by humans (start the evacuation procedure). This loop is called OODA (Observe, Orient, Decide and Act) [see Wikipedia on OODA].

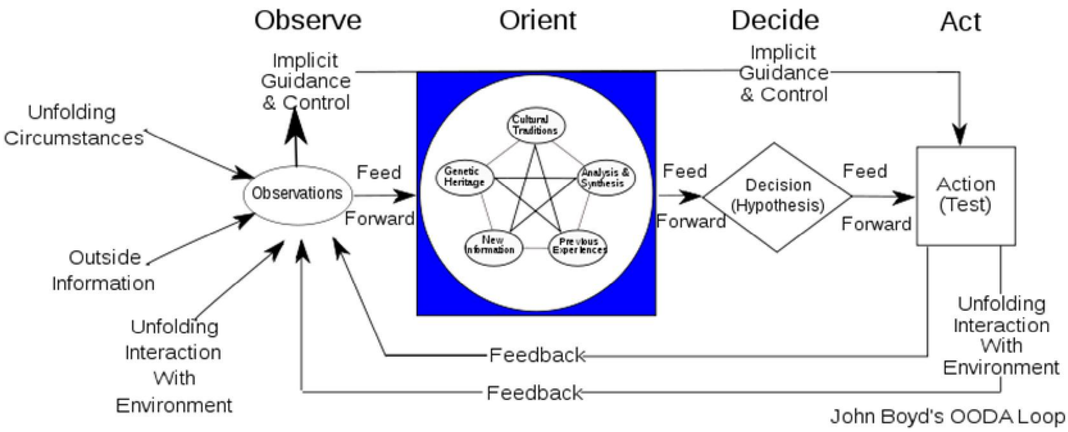


Figure 2-9 The OODA loop

Based on the OODA loop TNO has developed a model for Network Adaptive Interactive Hybrid System (NAIHS)[kes06], which organises this loop into collectors, situational awareness, decide on action and effectors, see Figure 2-10. In the flood control situation, the collectors are the sensors and the sensor network. The effectors are the valves and actions of people. Both are outside the scope of this project, as explained in the previous paragraph.

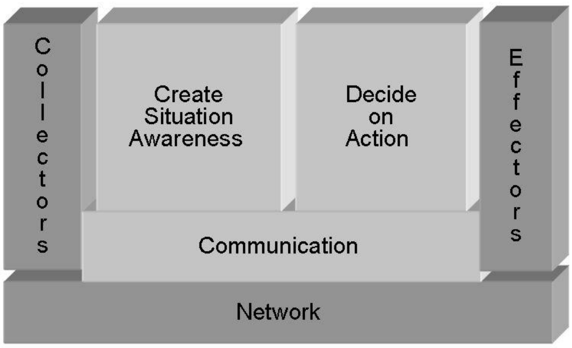


Figure 2-10 TNO Network Adaptive Interactive Hybrid System (NAIHS) model

The core of the flood control business architecture is to get situational awareness and to decide how to act on it. When those activities are made robust the business architecture will be robust. The provisioning and use of information about dikes and flooding will be robust.

Making robust means be able to answer the following questions and follow the proposed working methods:

In regard to situation awareness:

- Determine and if possible rise the quality of the used sensor data and information from other organisations inside the flood control system or from external sources.
    - *Data and information quality*
        - What is the quality/reliability of the acquired sensor data?
            - Does the sensor still operate? Do we get any data at all?
            - Is the data still useable? Is there a drift in the calibration?
        - What is the quality/reliability of the information from other the organisations within the flood control system?
        - What is the quality/reliability of the information from other the organisations outside the flood control system?
            - Weather stations (KNMI)
            - other external data sources
    - *Combine results*
        - Use more then the minimum number of sensors (inputs) to be able to get overlap between the measurements which can enhance the reliability of the measurements.
        - Use data and information of your neighbours about the area around your mutual border. This gives you more information about your own area.
    - *Predict input data*
        - If an input is (temporarily) unavailable (broken sensor), try to predict its state in order to continue operation as long as possible. Of course the reliability of the prediction is lower than actual measurements.
    - *Modelling*
        - Use not only models about positive situations, but also negative modelling. What is the change the dike will survive and what is the change the dike will collapse. Using different models for both questions and correlate the answers will enhance the reliability of your insight. Of course it must also be combined with the reliability numbers of the used input data and information.
        - Use also indirect data sources (like weather forecasts) to relate with your own findings. Enhance in such a way the quality of your own findings.
        - Determine important quantities (like dike stability) on more than one manner. If they contradict, something is wrong, perhaps an indication for faulty sensors, software faults, etc.
    - *Input for "decide on action"*
        - End up with calibrated insight and the reliability of this insight: The dike stability is at the moment 0.7, with a reliability of 75%.

In regard to Decide on action:

- *Correlate inputs*
  - Correlate the results of different inputs to see if they add up. The dike along a long river has probably more than one dike manager. The insight and predictions of these dike managers should be inline with each other, the river flows and high water will eventually reach also the next dike manager's dike segment.

- Be able to take over the task of a neighbour, in case of failure all tasks can be fulfilled by an other system, person, organisation, …
  - Perform this role also in normal situations to avoid unfamiliarity during crisis situations.
  - Make in normal situations also a (simple) prediction of the situation of your neighbouring dike manager. If they stop operating, still has some (less reliable) insight on the situation is available.

2.5.3 Implemented on the roles

This paragraph implements the above questions and working methods about making the business architecture robust, for each of the identified roles.

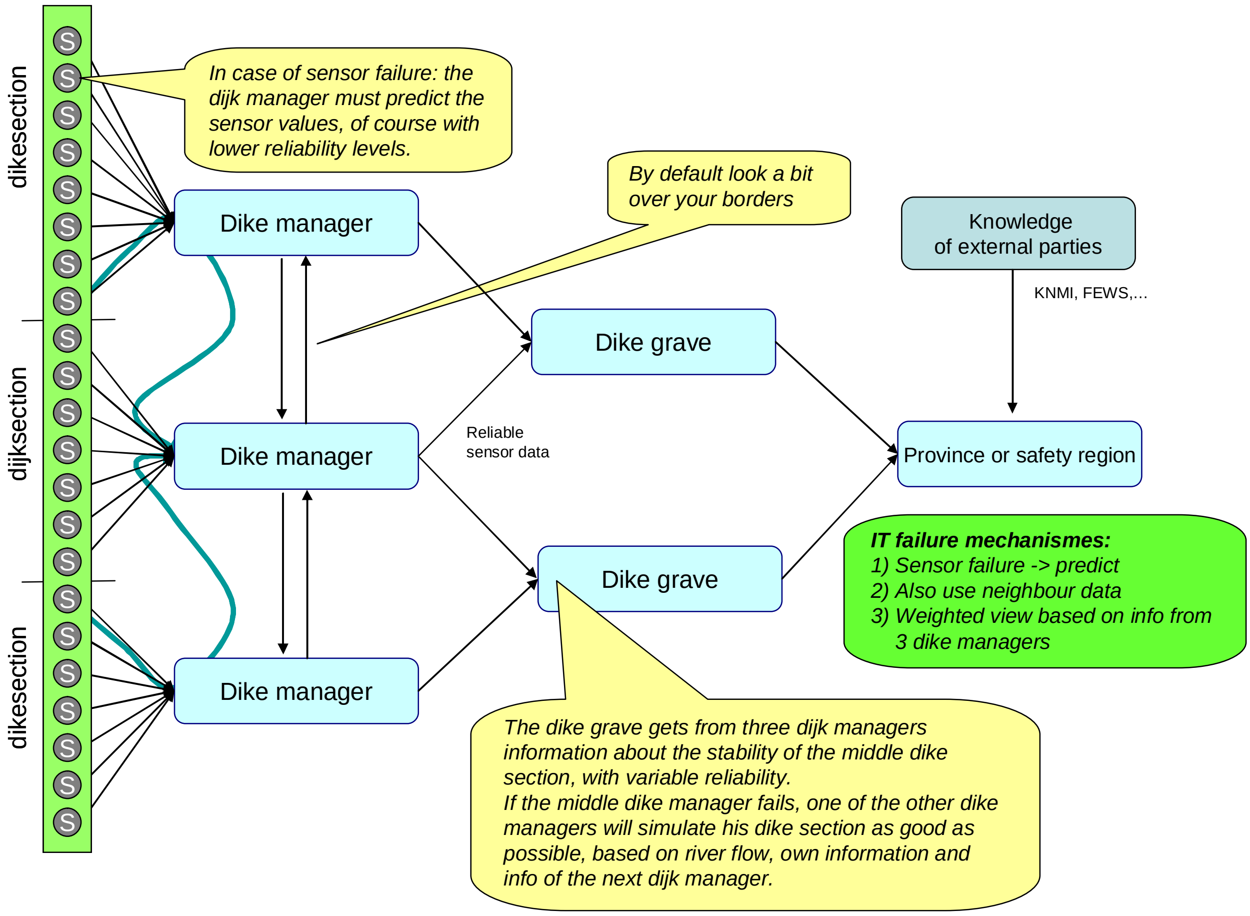


Figure 2-11 Robustness options of different roles in the flood control system

In the context of the Flood control system the roles dike manager, dike grave and country water manager should be able to perform some key tasks in order to let the system design work.

The dike manager should be able to perform the following tasks like:

- Indicate what the quality of the used sensor data is and work with reliability indications for all sensor data.
- Predict missing or wrong sensor data
- Combine data from neighbour sensors
- If applicable, use some sensor data from the neighbouring dike managers.
- Be able to take over the role of your neighbour dike managers

The Dike grave should be able to perform the tasks like:

- Indicate what the quality of the used sensor data is and work with reliability indications for all sensor data.
- Predict missing or wrong dike stability
- Combine data from neighbour dike graven
- If applicable, use dike insight from the neighbouring dike graves.
- Be able to take over the role of your neighbour dike graves
- Correlate the inputs of the dike managers to see if they form a consistent view on the water situation. Dike along a river should report one after the other higher water levels.

The Country manager should be able to perform the tasks like:

- Indicate what the quality of the used sensor data is and work with reliability indications for all sensor data.
- Work with reliability indications for all dike stability.
- Correlate insight from dike graves with neighbouring countries (Germany and Belgium) if applicable.
- Correlate the inputs of the dike graves to see if they form a consistent view on the water situation. Dike along a river should report one after the other higher water levels.

3 Understanding the Dutch water safety management situation

In the previous chapters different roles in the water safety management where already mentioned sometimes. This chapter put the different roles together in a normal operational situation and in a crisis situation. The roles that are my no means complete, the actual water safety management chain is much more complicated than outlined here but it is sufficient for the purpose of the project. To show the concept of organising different sensor streams across organisational boundaries it is not necessary to be complete in the sense.

This use cases, actors en organiations that are used throughout the whole project are outlined here in order to understand the upcoming chapters.

3.1 Water safety management chain

In the water safety management chain, a lot of independent organizations act. Together they make sure we are protected as much as possible from the water. If flooding occurs, appropriate action will be taken. In short, they keep our feet dry.

In this project we focus on a subset of all these organizations:

- *The water boards*
  Their responsibility is maintenance of levees and the management of a specific water flow area within the Netherlands, including the river dikes.

- *RWS (Rijks Water Staat)*
  Is responsible for sea – and river dikes

- *The safety regions*
  Are responsible for the safety of its citizens and crisis management within a divided geographical area (also see the Appendix for a map of the safety regions).

Figure 3-1 these organizations and their relations are depicted in a normal, operational situation. Dike management, water boards en RWS are responsible for reporting about the status of the dikes to the provinces. The provinces report an overview of the current dike status and flood chances to the national government.

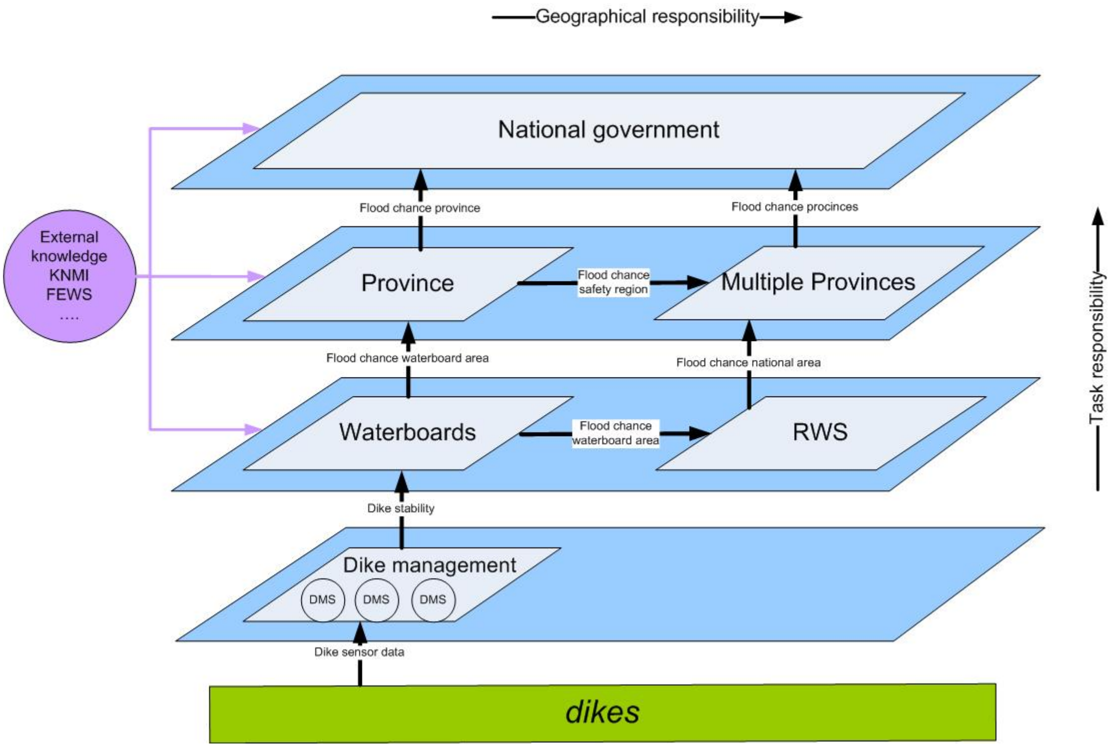


Figure 3-1: Relationships between organisations within the water management chain in operational situation.

In a situation of crisis, other organisations become involved in het water safety management chain. The provinces do not have an active role in crisis management. During crises, the Netherlands is divided in 25 safety regions (also see Appendix). These safety regions report directly to a national crisis team. This situation is illustrated in Figure 3-2. Safety regions and national crisis teams are responsible for crisis management in general, not only flooding, bus also chemical, airplane crashes, etc.

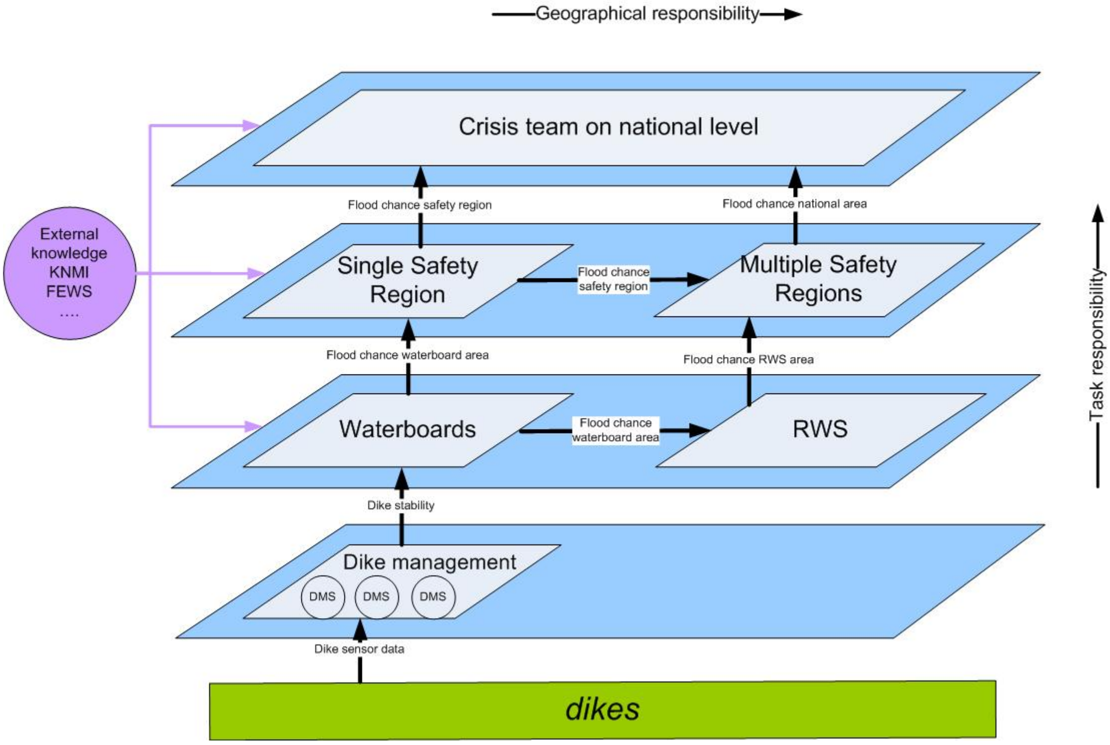


Figure 3-2: Relationships between organisations within the water management chain in crises situation.

In the Netherlands, the organisations responsible for the dikes are linked to the type of dike. The water boards are responsible for the river dikes and the surrounding area. RWS is responsible for the sea dikes and the protection against sea flooding. Both organisations use dike managers to inspect their dikes, e.g. visually.

In
Figure 3-1 and Figure 3-2: Relationships between organisations within the water management chain in crises situation., the geographical scale of responsibility of the organisation increases from left to right. A province is a smaller area than the entire nation, a water board has a smaller geographical area to manage than RWS. In both cases, their functional task is almost the same: providing safety for the citizens and managing the water flow.

From bottom to top, the task responsibility of the organisations increases. The dike manager monitors the dike and reports dike stability to the water board or RWS. The water board or RWS converts the dike stability, using external knowledge, into flood chance indications. They also construct an overview of the dikes in their region with the 5 yearly test (5-jaarlijkse toets). Based on their own overview, each water board informs the province about the chances of occurrence of a flood. These indications are passed to the province and national agencies.

In the water safety management chain, a lot of independent organizations act. They have different, independent ICT systems. During a crisis, these organizations need to be able to share a certain amount of information. The amount and type of information depends on the phase, as described in the previous paragraph.

3.2 Levels of alert in crisis situations

From “normal” to “crisis”, the system will go through a number of phases (“opschaling” in Dutch). For the national “High water and storm tide crises in the Netherlands” [rws08], a number of phases are defined. The phasing procedure is described in [rws08] and in an FC2015 report [hkv08]. In these documents, the word "phasing" means the act of changing the current phase to a higher coordination phase, based on the phasing criteria. In the current document, we adopt the same definition. The phases are shown in Table 3-1. In each phase, activities are defined, together with responsibilities and organisations involved. The phasing criteria for the large rivers and lakes are defined in [rws08]. These criteria are based on hydraulic and meteorological circumstances, and on conditions of water defences. Individual water boards have their own criteria for the water bodies and defences in their regions.

Table 3-1: Coordination phases, their characteristics and their reference levels [rws08, hkv08]

Phase	Characteristic features	Reference level
Stable phase	Daily business	Stable level
Coordination phase 0	Preventive measures	Warning level
Coordination phase 1	Regional decision making	Alarm level
Coordination phase 2	Interdepartmental synchronisation	Critical level
Coordination phase 3	National decision making	Normative water level

In case of a threat of flooding, where the safety of dike ring areas (dijkringgebieden, see Appendix) is affected, asynchronous phasing will be applied [rws08]. Asynchronous phasing is applied based on a founded estimate by specialists that extreme situations that can lead to floods *might* occur. The estimate is based on e.g. middle-term meteorological forecasts in combination with the hydraulic situation in the region. Most of the time, about 9 out of 10, the threat of a flood will not persist and a high water or storm tide will not occur. The criteria for asynchronous phasing are the threat of flooding and media exposure.

4 Business Architecture: requirements and use cases

The business architecture will answer the following key questions at project level:

- Who are the key people/organizations that will work with this system? These are the primary human actors of the system.
- What will they do? This is described in the high level key use cases.
- Where will they be located?
- Which information is needed? This is described in the information model.

This chapter will also describe the relevant principles, decisions and considerations. Another paragraph will focus on relevant non-functional and evaluation criteria.

This chapter therefore outlines the business requirements for the Flood Control System demonstrator. The requirements are specified in use cases for the:

- Regular situations
- Crisis situations

These use cases will be executed on two actual cases:
Case 1: A sensor system in the Livedijk - an operational Dutch sea side levee near Groningen, provided by water boards Noorderzijlvest.

Case 2: Several sensor systems in the IJkdijk – an experimental levee to understand the process of 'piping'. These locations will be detailed later in this document.

Table 4-1: Objectives and cases

	Use case	
Objective	Case 1	Case 2
Integrating multiple dike systems	x	
Sharing information across organisations	x	x
Responding to different information needs	x	x
Daily operation		x
Crisis situation	x	
Realised as	Livedijk	IJkdijk - piping

Besides these two cases 5 other case are described in order to understand the context in which a Flood Control System operates. Some of the scenario's are fictitious and other are scenario's that actually happened in the past for example the a flooding in 1953. These additional scenarios's can be found in the appendix of this document and are complementary to this chapter.

The use cases are based and verified by the following sources:

- Theses Enterprise Ontology for the flood control domain [mon09]
- Actors in crisis situations [den]
- Inspection of water barriers presented by Rutger Baaten & Jan Willem Vrolijk at the "Kennisdag inspectiewaterkeringen 2009" [baa09]

- Interviews with:
    - o The national committee to coordinate floodings (LCO)
    - o Calamity team water barriers of Rijkswaterstaat.

4.1 Scenario 1: regular monitoring situation

This scenario describes the regular usage of the flood monitoring system by multiple actors in various organisations. In the appendix additional use cases are added that show an extended line of thought how a flood Control System could be used. These will not be implemented with this demonstrator.

Figure below provides a schematic visualization of the use case steps. These steps will be detailed in sub paragraphs.

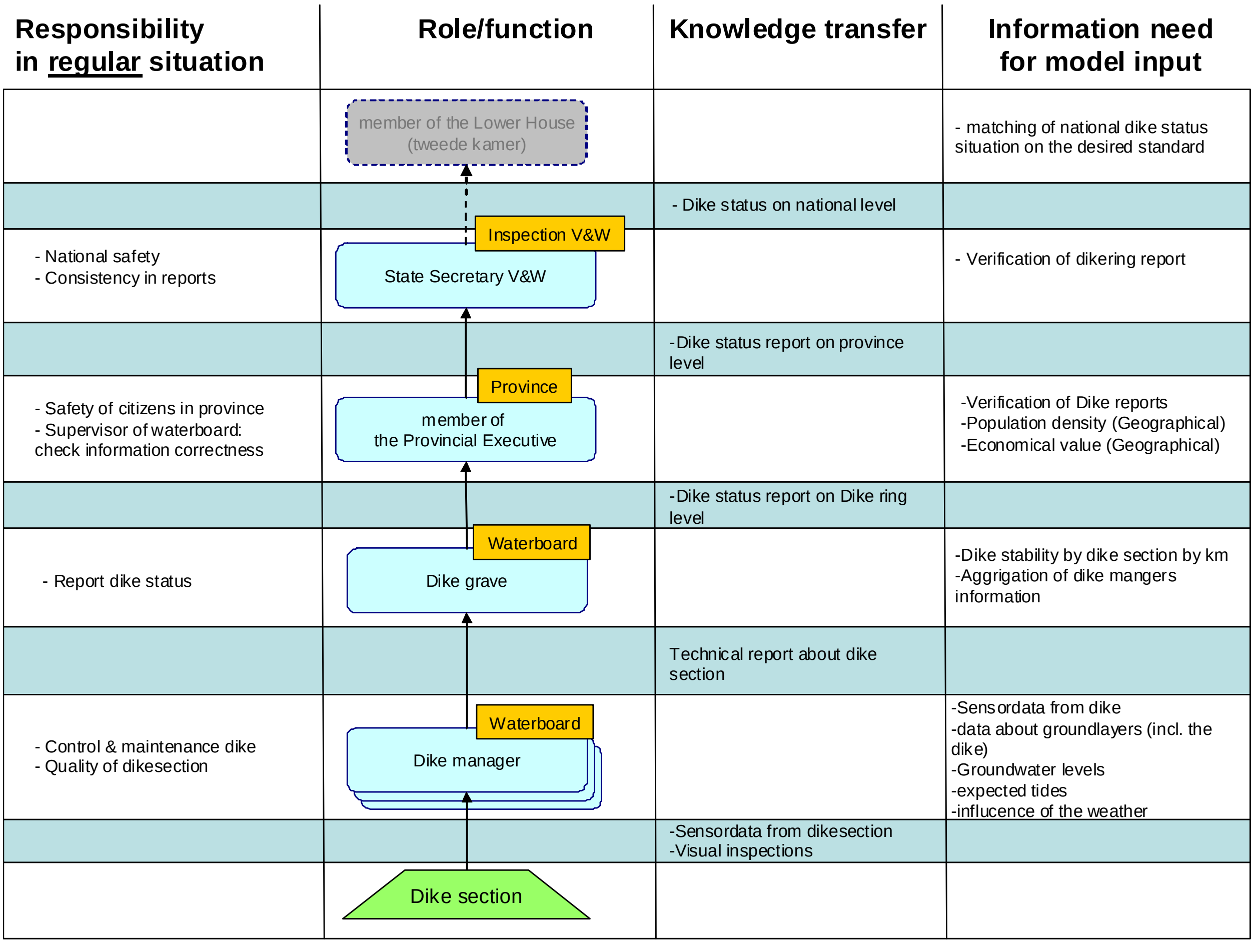


Figure 4-1: Roles and responsibility in a regular monitoring situation

Steps in this scenario:

1) Sensors in the levee are constantly reporting the status of the internal stability of the levee to the local Dike Monitoring System of that specific levee.

2) The dike manager in the office will check his levee management system to see the status and reports on a specific part of the levee (a ‘dijkvak’). The dike manager has to evaluate the quality and will create a Levee Status Report

(‘Dijkvakrapportage’) of the technical status of the levee. The report includes details and a conclusion of the quality:

a) “Good, up to design level”,
b) “Moderate, risks to fall behind design level in 5 years” or
c) “Bad, currently behind design level”

3) The Director of the water district (Dijkgraaf) needs to report the combined quality of all levees within his/her water district to proof the technical state of all levees. This report is called the Water District Levee Status Report (Dijkstatus rapportage’). This report is visible on the screen by the following information items:
   a) A map of the levee system of this water district with color coded the quality of each section of levee.
   b) A chart showing the percentage of the status (Good, Moderate, Bad) of the levees, expressed as a percentage of the total length of levees in the water district. This chart contains a line that indicates the average state of levees by other water districts to be able benchmark performance.
   c) A financial representation of the current cost and the estimated cost of levee maintenance and the amount of work being performed.
   d) A time series of the real-time aggregated stability sensor of one of the levees with a trend (history or forecast).
      The director can select this sensor trend line and decide to add this to the report as evidence that this levees needs special attention.

4) The head of the water department in the province or state (Gedeputeerde Water) needs to report about the safety of the people in the region and to evaluate the work of the water district. He will report a Province Levee Status Report (dijkringrapportage) to the national government. In order to submit this report he needs the Water District Levee Status report from the water districts that are present in this province. Additionally he needs the following information:
   a) Population data of people visibly on a map
   b) Economic value of an area presented on a map

   He will see in the system:
   - A map of the levee system in the province. He can toggle between the views: “quality of the levees”, “time to repair” and “cost of levee repair’.
   - A counter that shows what percentage of the levees is monitored in real-time.
   - The map is overlayed with color coded the population density
   - The map is overlayed with color coded the economic value of the area

   When he selects a levee the system will show with graphs and in text:
   - the economic value of the area
   - the amount of people protected by this levee
   - the impact of a breach after one hour, half a day and a day in Euros and lives lost.

   The “quality of levees” above is provided in real-time. In this regular scenario, the quality should be good and not varying, resulting in a dull picture.
   To complete Water District Levee Status Report he evaluates the work of the water board and concludes a safety report by
   - Selecting a levee ring area
   - Select a water board assessment: good, average, bad
   - Select a grade for “safety of public”: good, average, bad.
   - Select a grade for “safety of economic activity”: good, average, bad.

5) The inspection department of the government (Staatssecretaris V&W) is responsible to report the safety whole country in a consistent manner. This report is called: National Status of Levees. The report will check the levee status according to the current norm of possible flooding in 1:10000 year. As an input the reports from the provinces is needed. The system will present:
   a) A map with colour coded areas for the current levee design levels, safety and economic status of the area.
   b) A map that show the situation in steps of 5 year, with an outlook of 50 years.
   c) Figures that show the amount of levees meets the norm, in km and as percentage.

This scenario is broken up in autonomous testable use cases in the tables as below.

Use Case S100	The Flood Control System continuously receives sensor data for a levee segment
Actor	Flood Control System (FCS)
Input	None
Event Flow	• The FCS receives sensor data from the Dike Monitoring System to which the sensors are connected. • The FCS stores this data in raw format. • The latest sensor data is ready to be displayed in the FCS
Output	The sensor data stored in FCS and can be seen through a web browser.
Preconditions	The levee is stable
Post-conditions	The levee is stable
OODA Phrase	Observe

Use Case S101	The Flood Control system receives the forecast stability for a levee segment
Actor	Flood Control System (FCS)
Input	Sensor data
Event Flow	• The FCS sends the sensor data to the forecasting system. • The FCS receives the forecasting stability of a levee segment. • FC stores this forecasted stability and it is made ready for display.
Output	The forecasted levee status is stored in the FCS and can been seen through a web browser.
Preconditions	The levee is stable
Post-conditions	The levee is stable
OODA Phrase	Orient

Use Case S102	Dike manager checks the status on a specific part of the levee
Actor	Dike Manager (DM)

Input	None

Event Flow	• DM logins the FCS.
	• DM chooses to check the status of one specific part of the levee as an asset.
	• DM can check the following detail of the levee:
	  • Levee construction detail
	  • Accepted design levee
	  • Prior and scheduled maintenance
	  • Visual inspection reports
	  • Actual sensor values, including historic values
	  • Forecasted levee status
	• DM creates the Levee Status Report ('Dijkvakrapportage') Based on the detail of the levee the Dike manager creates a report of the levee status by selecting one of three quality levels.
	  1. Good, up to design level
	  2. Moderate, risks to fall behind design level in 5 years
	  3. Bad, currently behind design level
	• FCS stores the report and makes it available to other applications

Output	The levee status is changed in the FCS The levee status is made available to other applications and will be sent to water district director.
Preconditions	The levee is stable
Post-conditions	The levee is stable
OODA Phrase	Orient

Use Case S103	Water board director (Dijkgraaf) creates a report of quality of the whole levee system in his water district
Actor	Director of water board (DW)
Input	None

Event Flow	• DW logs into the FCS.
	• DW creates the report of levee in his water district. The report contains the following information on the levee system.
	  • A map of the levee system of this water district with color coded the quality of each section of levee.
	  • A chart showing the percentage of the status (Good, Moderate, Bad) of the levees, expressed as a percentage of the total length of levees in the water district. This chart contains a line that indicates the average state of levees by other water districts to be able benchmark performance.
	  • A financial representation of the current cost and the estimated cost of levee maintenance and the amount of work being performed.

	- A time series of the real-time aggregated stability sensor of one of the levees with a trend (history or forecast). - The director can select this sensor trend line and decide to add this to the report as evidence that this levees needs special attention. - DW sends this report to head of the water department.
Output	Report on the levee quality in the district.
Preconditions	The levee is stable
Post-conditions	The levee is stable
OODA Phrase	Orient

Use Case S104	Head of the water department in the province of state (Gedeputeerde Water) checks the report from water districts in his province.
Actor	Head of the water department (HW)
Input	None
Event Flow	- HW logins the FCS - The HW is able to see: - A map of the levee system in the province. He can toggle between the views: “quality of the levees”, “time to repair” and “cost of levee repair’. - A counter that shows what percentage of the levees is monitored in real-time. - The map is overlayed with color coded the population density - The map is overlayed with color coded the economic value of the area - When he selects a levee the system will show with graphs and in text: - the economic value of the area - the amount of people protected by this levee - the impact of a breach after one hour, half a day and a day in Euros and lives lost. - To complete Water District Levee Status Report he evaluates the work of the water board and concludes a safety report by - Selecting a levee ring area - Select a water board assessment: good, average, bad - Select a grade for “safety of public”: good, average, bad. - Select a grade for “safety of economic activity”: good, average, bad.
Output	The status of the Water District Levee Status Report will be changed to evaluated. The report will be made available to other applications.

Preconditions	None
Post-conditions	None
OODA Phrase	Orient

Use Case S105	Staatssecretaris V&W reports the safety of the whole country in a consistent manner.
Actor	Staatssecretaris V&W (SV)
Input	None

Event Flow	• SV login the FCS.
	• SV can report the levee status of the whole country with the following information.
	    • A map with color coded areas for the current levee design levels, safety and economic status of the area.
	    • A map that show the situation in steps of 5 year, with an outlook of 50 years.
	    • Figures that show the amount of levees meets the norm, in km and as percentage.

Output	A report of national levee is generated.
Preconditions	None
Post-conditions	None
OODA Phrase	Orient

4.2 Scenario 2: Monitoring in a crisis situation

In this case a crisis is described. Water levels in the river rise to normative water levels, corresponding to coordination phase 3 (see Table 3-1). This means that decisions are made on national level.

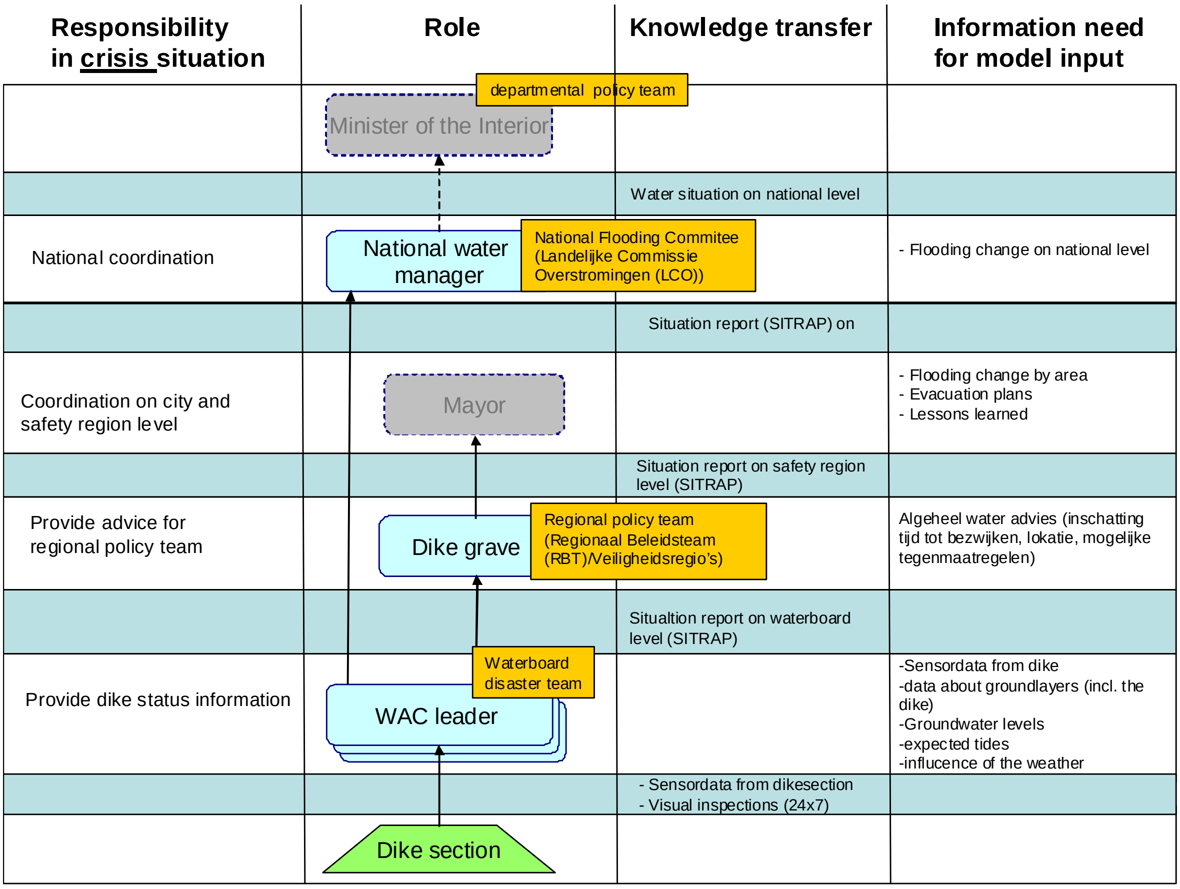


Figure 4-2: Role and responsibility in a crisis situation

Steps in this scenario:

1) Water level rises, heavy rainfall. Sensors show alarming values which translate to exceeding thresholds on dike stability.

2) Calamity team is formed, headed by the "WAC leader". The team consists on experts on hydrology, engineering, dike inspectors. The team needs to report on dike stability to the Director of the water board (dijkgraaf) called a water board situational report (SITRAP). Information used to make this report is:
   - sensor data (e.g. water tensions) translated to dike stability
   - subsurface information of dike
   - current situation on and forecasts of discharges, groundwater levels, weather, tides and wave heights

   The virtual sensor is the current quality at various dike locations (sections).

3) The regional crisis team (regionaal beleidsteam), part of the safety region is formed when potential disasters span multiple municipalities. The team consists of the fire department, police, emergency services, experts on water and is headed by the mayor. The team provides an integral report and advice on the crisis situation to the mayor. The director of the water board is part of this team for the advice on water related issues. He reports on an estimate of time to failure, location of failure, possible counter measures and affected area of flooding. The virtual sensors deliver a forecast of levee quality, an estimated time to failure and a flood map.

4) Parallel to step 3, the calamity team of the water board reports the SITRAP to the National Flooding Coordination Center (Landelijke Commissie Overstromingen, LCO). Their task is to facilitate the regional crisis coordination (e.g. with equipment, sand bags) and to protect the national interest. The LCO reports to the Minister. He is the only one who can overrule the mayor when national interest demands so. The LCO forms an estimate on chances of flooding for all threatened areas, beyond the geographical area covered by the regional crisis team. They also have an overview of resources for counter measures. The estimates on chances of flooding are based on the virtual sensor (levee quality and flood map) of the director of the water board. A flood map is part of the information in this step. They create a virtual sensor related to priority of measures on a national scale. Additionally, the LCO delivers a virtual sensor that specifies the coordination phase (see Table 3-1). An evacuation virtual sensor is available, which can be passed on to other levels.

5) Water level still rises. Decision to evacuate is made, based on information from the FCS. Evacuation sensor is turned “on”. All levels receive the evacuation sensor immediately.

6) Evacuation proceeds. Disaster plans are coupled to the FCS. Resources can be allocated by the LCO.

7) Water levels fall. Sensors still measure increase in dike stability and indicate when the levees are stable again. This can take some time.

8) Director of water board estimates time to stable dike situation. This time is indicated by the virtual sensor equivalent to virtual sensor of estimated time to failure.

9) According to sensors and visual inspections, the levees are stable again. Evacuation sensor is turned off. People can return to area.

10) Evaluation.

This scenario is broken up in autonomous testable use cases in the tables as below.

Use Case S201	Sensors show alarming values when water level rises to certain stage
Actor	Robust Monitoring Platform (RMP)
Input	Water level
Event Flow	● Sensor value is updated by reading the water level. ● Sensor scoreboard turns into RED when water level rises beyond the dike stability threshold. ● RMP notifies WAC leider to make SITRAP report.
Output	Notification to WAC leider
Preconditions	Water level is under the threshold level
Post-conditions	System sensor scoreboard shows RED
OODA Phrase	Observe

Use Case S202	Calamity team submits the SITRAP report to Landelijk Commissie Overstromingen (LCO)
Actor	Calamity team (CT)
Input	Description of the current situation and suggestions for possible decision
Event Flow	● CT logins the RMP platform. ● CT creates a SITRAP report. ● CT requests information from the RMP platform. Information used to make report includes: ● sensor data (e.g. water tensions) translated to dike stability. ● Subsurface information of dike. ● Current situation on and forecasts of discharges, groundwater levels, weather, tides and wave heights. ● CT inputs the description of the current situation based on the facts and also give decision suggestions. ● CT sends the report to LCO.
Output	A report is sent to LCO
Preconditions	None
Post-conditions	None
OODA Phrase	Oriented

Use Case S203	In the crisis situation Landelijk Commissie Overstromingen(LCO) assigns new value to two virtual sensors. One virtual sensor is the priority of measures on a national scale while the other is coordination phase virtual sensor.
Actor	LCO
Input	SITRAP report
Event Flow	● LCO receives the SITRAP report. ● LCO requests information from RMP platform about the situation. Information includes ● resources for counter measures. ● Levee quality of the director of the water board ● Flood map of the director of the water board ● Based on the facts LCO forms an estimate on chances of flooding for all threatened area. ● LCO assigns new value for the priority of measure on a national scale. ● LCO assigns new value of the coordination phrase.
Output	- New value for the priority of measures on a national scale - New value of the coordination phrase.

Preconditions	SITRAP is received
Post-conditions	None
OODA Phrase	Decide

Use Case S204	Evacuation decision is made. Evacuation virtual sensor is in 'ON' status.
Actor	LCO
Input	None
Event Flow	● Evacuation decision is made by LCO. ● LCO set the evacuation virtual sensor in 'ON' status.
Output	Evacuation sensor is in a value of 'ON'
Preconditions	Evacuation is decided.
Post-conditions	None
OODA Phrase	Decide

Use Case S205	Disaster plan is executed.
Actor	RMP
Input	None
Event Flow	Evacuation plan is decided. Based on the region RMP executed the disaster plan designed.
Output	None
Preconditions	Evacuation is decided.
Post-conditions	None
OODA Phrase	Action

Use Case S206	Water level falls and robust Monitoring Platform(RMP) indicates the time needed to get the dike stability back to normal status.
Actor	RMP
Input	Water level
Event Flow	● Water level starts to fall. By reading the water level sensors increases the dike stability. ● Water level continues falling. After analyzing the water level reading for a certain time RMP indicates the time that dike stability will return back to normal status again. ● RMP assign the indicating time as the value of the virtual sensor.
Output	The time needed to get dike stability back to normal.

Preconditions	In Evacuation status.
Post-conditions	None
OODA Phrase	Oriented

Use Case S207	According to the sensor reading and visual inspection, LCO set the evacuation sensor to 'OFF' status
Actor	LCO
Input	None
Event Flow	● LCO requests sensor readings from RMF. ● LCO did visual inspection on the real dike situation. ● LCO set the evacuation virtual sensor to 'OFF' status.
Output	Evacuation virtual sensor changes to 'OFF' status.
Preconditions	In Evacuation status.
Post-conditions	None
OODA Phrase	Decided and Action

4.3 Actor Brief Descriptions

This paragraph summarizes all actors defined in the use cases above.

For the regular situation the following human actors are identified:

- Dike manager: works at a water board / water district.
- Director of water board (Dijkgraaf).
- Gedeputeerde Water: responsible for safety of citizens of province.
- State secretary of Public Transport and Waterworks, inspection department (Staatsecretaris van Verkeer en Waterstaat, inspectie voor verkeer en waterstaat).

For the crisis situation the following additional human actors are identified:

- WAC leider (water board): Head of calamity team of the water board.
- Dijkgraaf (regional beleidsteam): Director of water board and part of the regional crisis team (regionaal beleidsteam). He reports on an estimate of time to failure, location of failure, possible counter measures and affected area of flooding.
- Landelijk water manager: head of National Flooding Coordination Center (Landelijke Commissie Overstromingen, LCO)
  Their task is to facilitate the regional crisis coordination (e.g. with equipment, sand bags) and to protect the national interest. The LCO reports to the Minister. He is the only one who can overrule the mayor when national interest demands so.
- Experts on hydrology
- Experts on engineering
- Dike inspectors

In addition system actors are identified:

- The sensor system(s)
- The predictive modelling system(s)

5 Information analysis

5.1 Use Case analysis

This paragraph provides more detailed information regarding the information need of the different roles. The use cases in previous chapter have been analysed to identify all information items. The relationship between information items will be defined in the Information Model: an Entity Relationship Diagram (ERD).

This will help create the user interface prototype that will display detailed levee information and provides the end user a way to modify and create new information.

Remark: In a crisis situation the same information will be provided only prioritized in a different way. E.g. In the regular monitoring situation the focus of the dike manager is the assessment status of the dykes within his area of responsibility. In a crisis situation maintenance and assessment information has less priority. The report provided in a crisis situation is called a SitRap (situational reports).

As a first step to visualization of the information the role dependent information need of each actor is described, split into 3 sections: continuous insight, continuous visualization and regular reporting.

5.2 Information model: Entities and attributes

The Entity Relation Diagram (ERD) describes the entities, the attributes related to each entity and the relations between the entities.

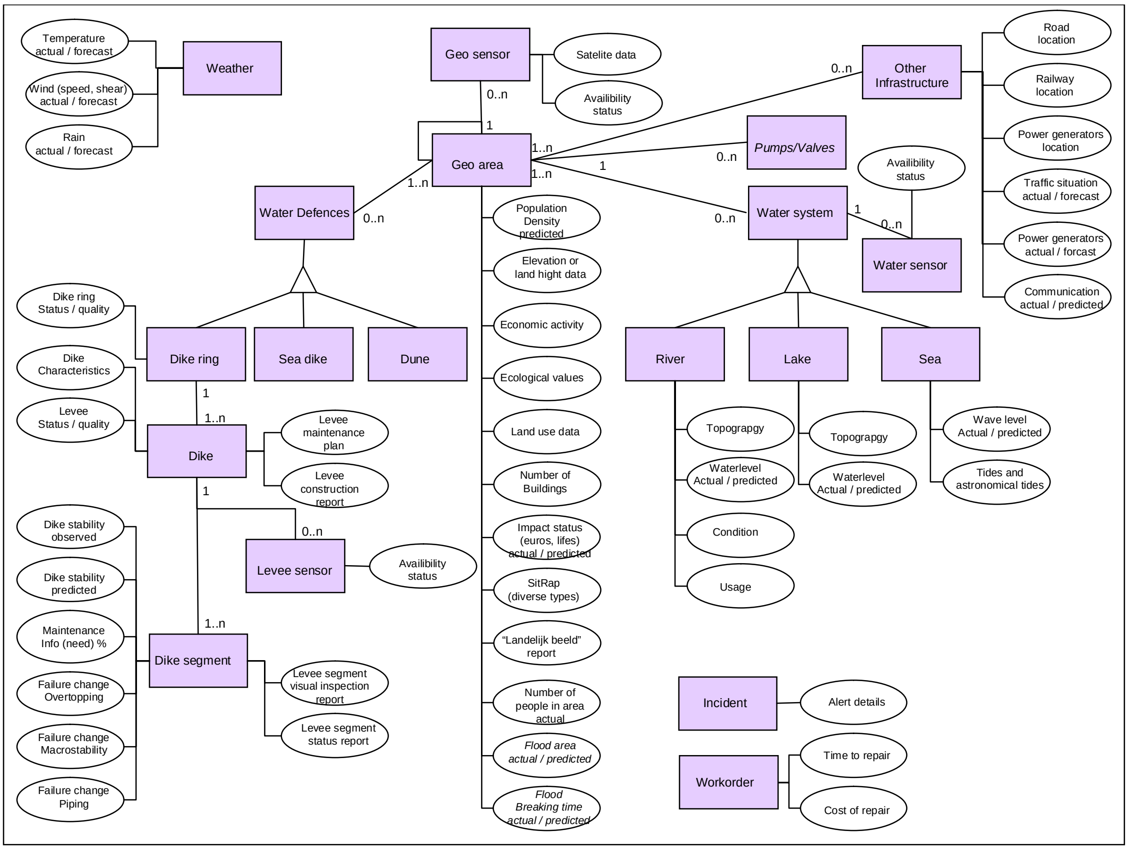


Figure 5-1: Entity Relation Diagram - Flood Control Room

The entities and attributes relevant to the dike monitoring system are listed in the following picture.

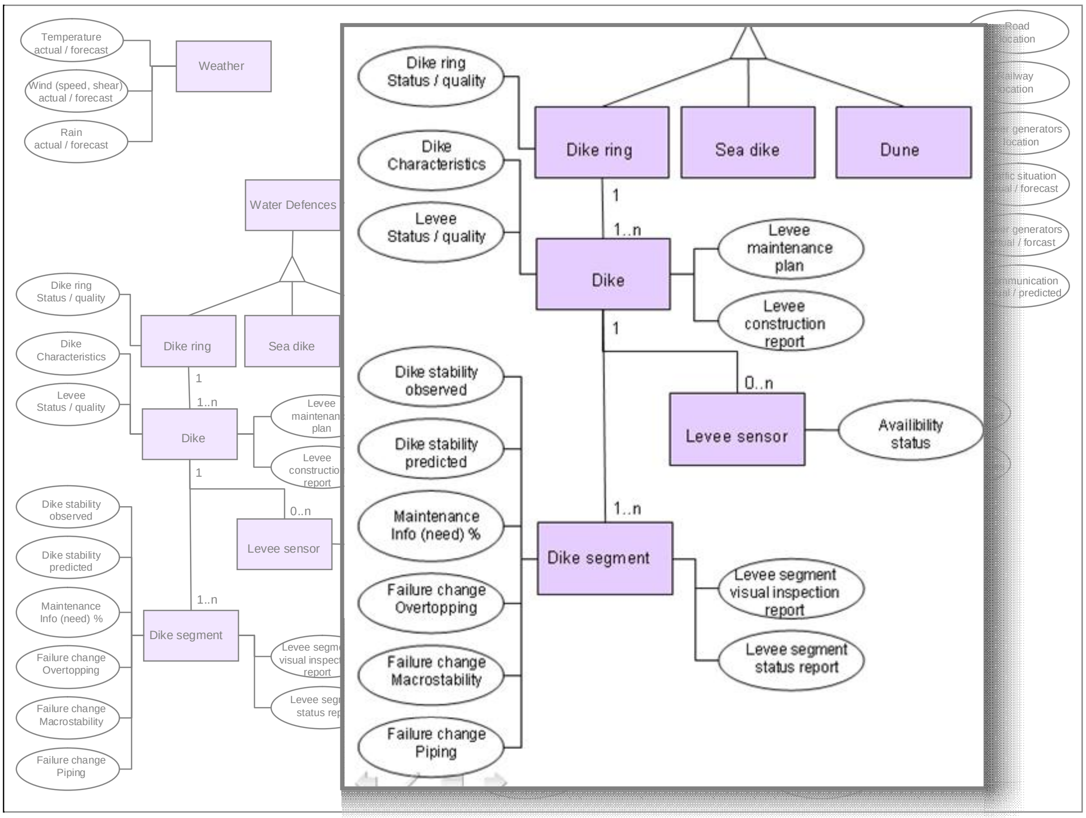


Figure 5-2: Entity Relation Diagram – Dike related entities and attributes

6 User Interface wireframe

The chapter describes the user interface prototype independent of technology. It serves as a reference for implementing Flood Control Systems. It cleanly identifies what is important for the end-user given the use cases as described in previous chapters. Based on this user interface Wireframe the implementation of the prototype can be done using specific products and technologies.

6.1 Selection of User Interface reference model

As the base for a user interface design an reference user interface model can be used that has already proven itself. The Flood Control System deals with two situations

- Regular operations
- Crisis situations

6.1.1 Control room and OODA reference models

For crisis situation standard user interface reference models for control rooms can be used. The characteristics for a control room situation match the characteristics of a Flood Control System:

- Stressful situation / high pressure of work / tiredness
- Various disciplines work together intensively
- Continuous overview actual situation
- Continuous exchange of information
- Consider different alternatives and consequences in little time
- React immediately on alarm situations and alerts
- Overcome loss of information (euro's, lifes)
- Overcome error situations (euro's, lifes)
- Environmental factors: noise, pressure of work, night/artificial light, etc.

Figure 6-1: Control Room set up - Examples

To handle the above characteristics a clear handling process has to be defined in the user interface such as the OODA decision cycle process as defined by Boyd [boyd]. This decision process clearly identifies the following steps which are very relevant to a Flood Control System and should be reflected in the user interface.

- Observe: sensor data coming in.
- Oriënt: create a forecast on the stability
- Decide: decide on the action and make this available to other actors in a situation report
- Act: track the execution of the decisions

Also see the appendix for futher explaination of the OODA decision cycle.

Systems that are used in crisis situations should not be different from the systems used in daily regular operations, because the user doesn't have time to learn the interaction with a new situation in a situation that rarely occurs. This is also a principle of the Dutch Ministry of Transport & Public Works.

Therefore the above OODA principle will be used for the prototypes in regular and in crisis situations.

6.1.2 Portal or Dashboard reference model

One of the key objectives of a Flood Control System is to bring different information together. The combined view on various information sources is what should enable the end user to make better and faster decisions.
This is typically being done with portal or dashboard applications. Portal or dashboard user interface models give the following additional advantages:

- A convenient, single point of access to multiple sources of information
- The ability for users to customize the appearance of their portal by choosing information appropriate for their work tasks.
- The ability for users to filter content for more convenient access to information based on their personal needs and interests.

Therefore the portal or dashboard user interface models will be used as inspiration to create the wireframe.

6.2 User interface wireframe

This section describes the concept user interface wireframe (concept). By adhering to the OODA loop a flow of user interface screens has been created. See the overview of this user interface flow below:

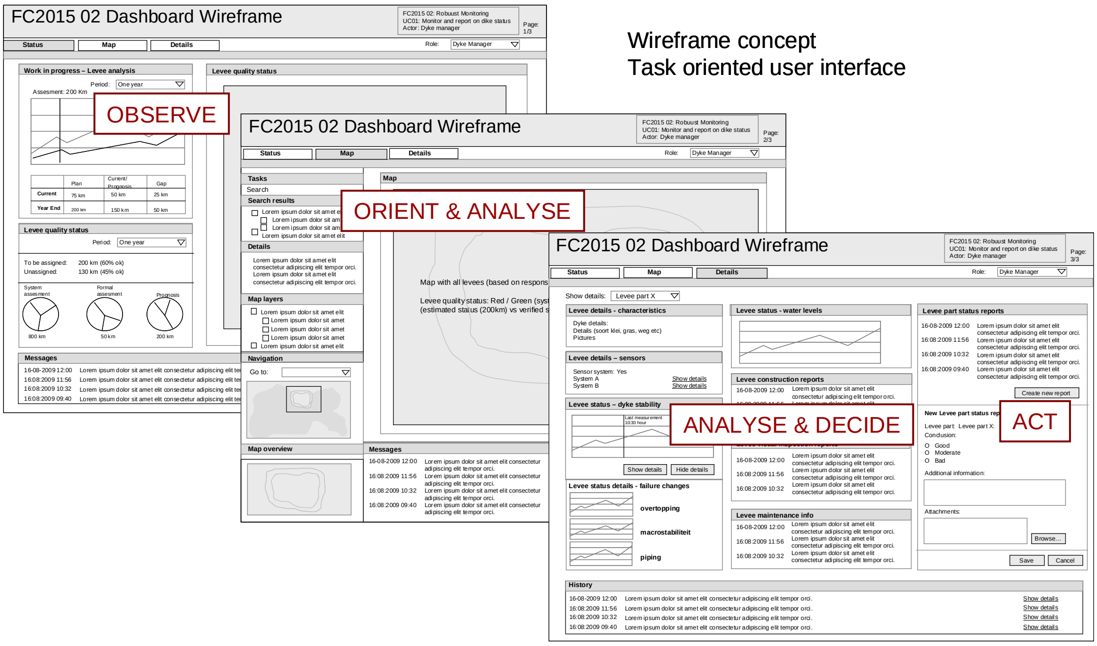


Figure 6-2: User Interface flow according to OODA and portal user interface models

In detail these three user interfaces will look the following for the role of a dike manager.

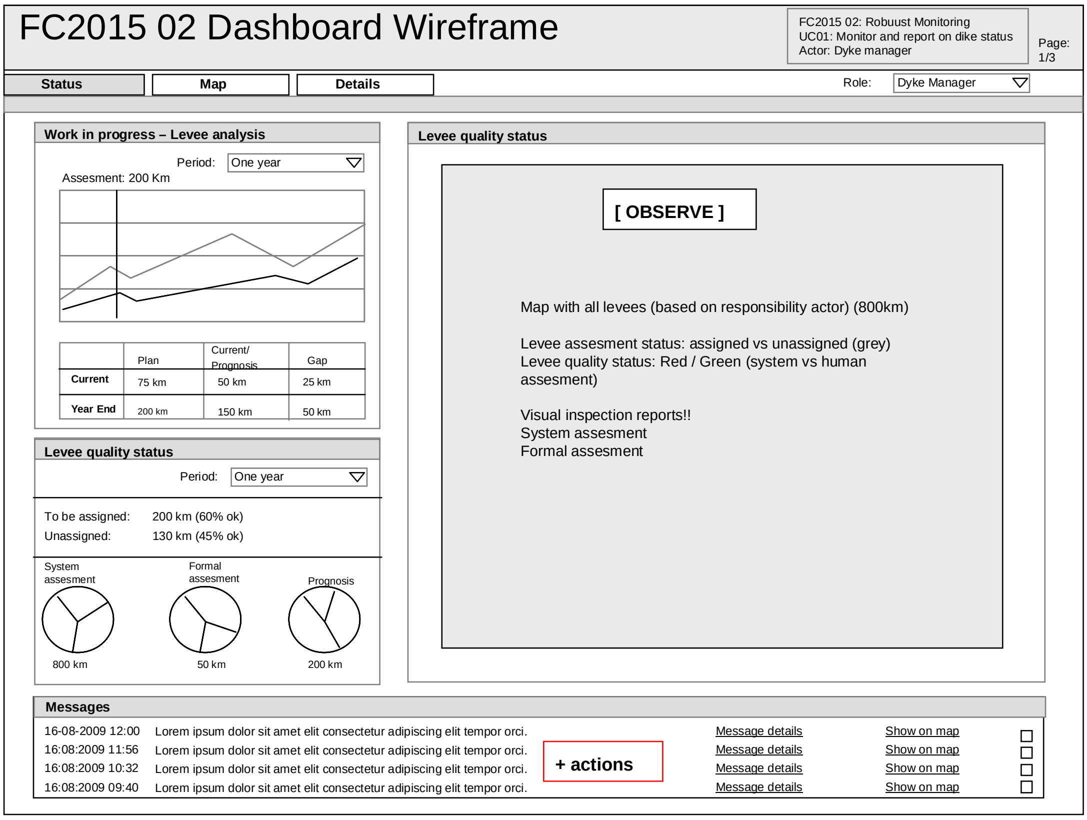


Figure 6-3: Wireframe – Status information

At the screen above the dike manager can see his current work tasks. He has for example 200 km of levees to evaluate and report about and currently he only has 50 km done. So he is presented with the next levee to evaluate. He also can see the status of the levee system under his responsibility. In addition he is presented specific messages from the call center, for example a call from a farmer that has seen unusual movement of a levee that the dike manager should check out.

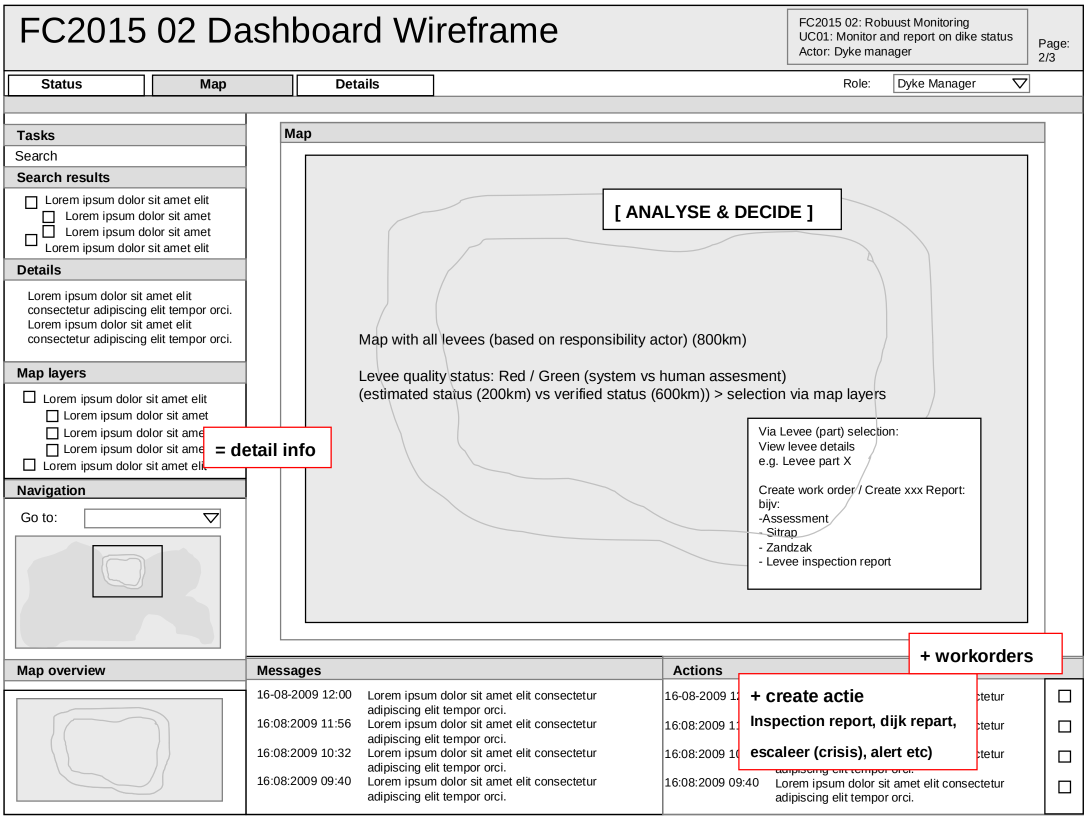


Figure 6-4: Wireframe – Map

On the screen above the user analyses the situation by examining all information sources. Levee stability forecasts are plotted on top of a GIS map to have a clear understanding of the levee system.

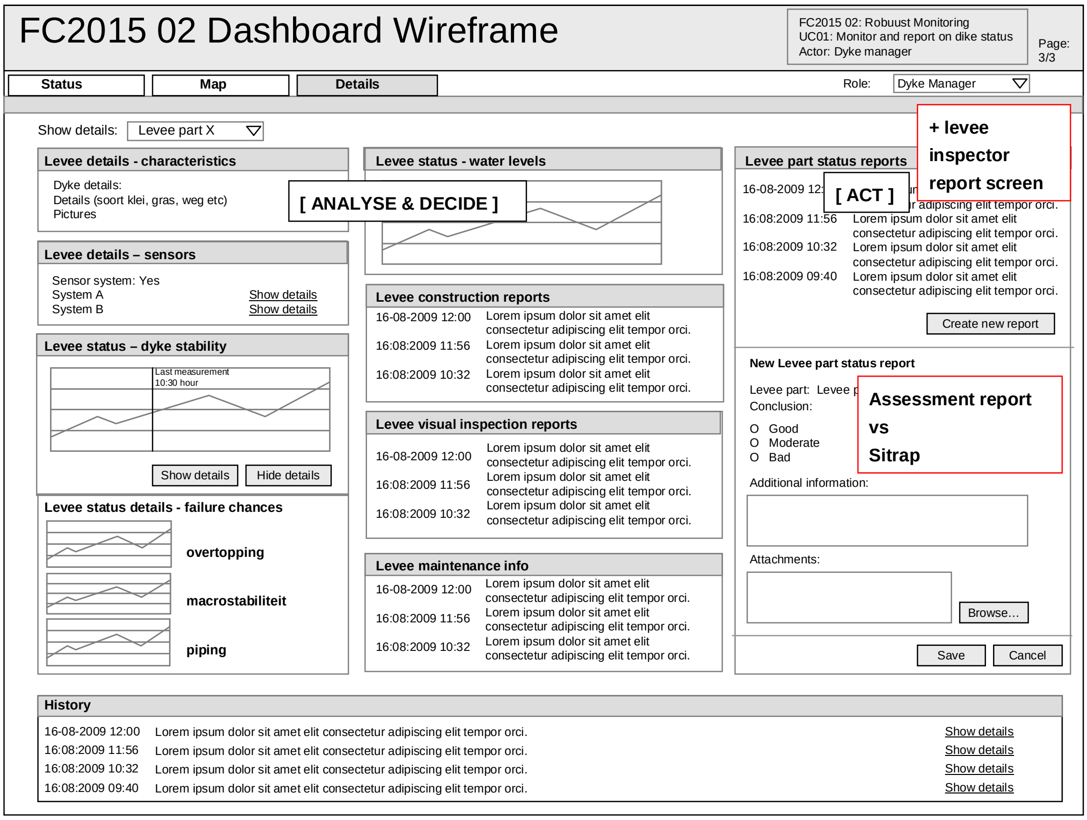


Figure 6-5: Wireframe – Details and reporting

On the screen above the dike manager can decide how to assess the levee stability based on all the information sources that have been brought together (inspection reports, sensor data, stability forecasts, prior maintenance, etc.).

7 Prototype implementation

This chapter shows the implementation of a few different roles in specific technologies.

7.1.1 Product and technology selection

To implement the prototype specific technologies have been selected that best fit the purpose of the demonstrator.

The dike manager needs a system to facilitate the management and maintenance of levees. Such systems are called asset management systems. Asset management is the art and science of making the right decisions and optimising maintenance processes in order to achieve higher quality assets (levees), control costs and optimise process efficiency (Institute of Asset Management (www.theiam.org))
IBM Tivoli Maximo was chosen to implement the role of the dike manager as it is a perfect fit from a functional perspective. And it is proven technology which is already deployed at 14 water boards in the Netherlands.

The infrastructure that is the basis for Flood Control System is WebSphere integration software which provides a very high reliable and scalable system. As this WebSphere integration software doesn’t have a user interface for the end user it will not be detailed here.

For roles like safety region, province etc. no specific software package are available. To implement this roles a generic software framework was used: Abobe Flex. Adobe Flex is a flexible, open source, software development package to create interactive user interfaces. For the roles implemented in Flex also the timeline concept was partially implemented as described in paragraph 2.3

7.2 Role: Dike manager implementation

Figure 7-1 shows the Start Page of Dike Manager. This screen will be the default entry screen when the Dike Manager logs into the system. The dike manager uses this screen to inform the daily operation work. Each of the components on the screen is explained as below.

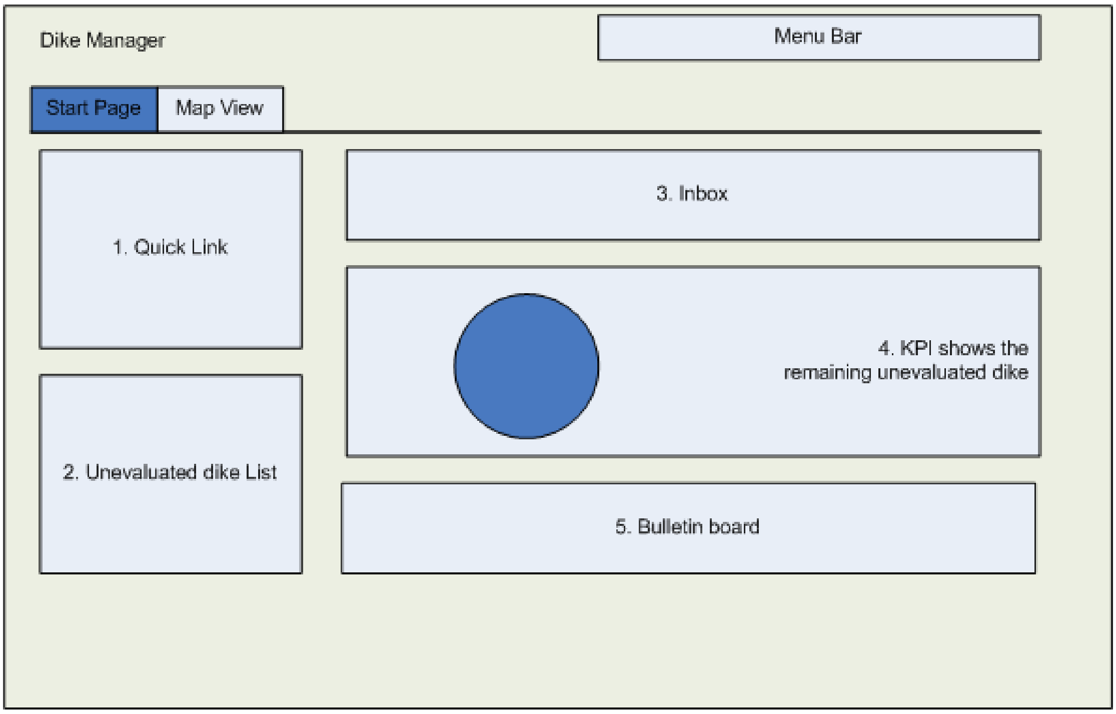


Figure 7-1: UI - Start Page of Dike Manager

1. **Quick Link:** Quick Link is the application which lists the frequently used application launchers. For example, dike manager can start creating a work order through the Quick Link instead of going through the menu.

2. **Unevaluated dike list:** It lists the unevaluated dike items. Dike manager can click on each item and goes to the Asset Page in Figure 7-1.

3. **Inbox:** Inbox lists the messages from the work place.

4. **KPI (key performance indicator):** This KPI shows the number of remaining unevaluated dikes. It gives Dike manager an overview of the work load. There will be 10 dikes in the system of which 3 are assessed. As soon as one is assessed you will see this indicator turn to 40% and the activity is removed from the unevaluated dike list.

5. **Bulletin board:** Bulletin board shows the messages from alarm or other systems. Messages will be expired after certain time period. It will shows the following example alarms:
   a) Farmer Jansen reported boiling water at the toe of the levee (this might be implemented through the ticket system in Maximo)
   b) Maintenance on levee 2 is not reported to be finished by contracter (implemented through work orders)
   c) Forecast of levee 4 tells you that stability is declining and requires attention.

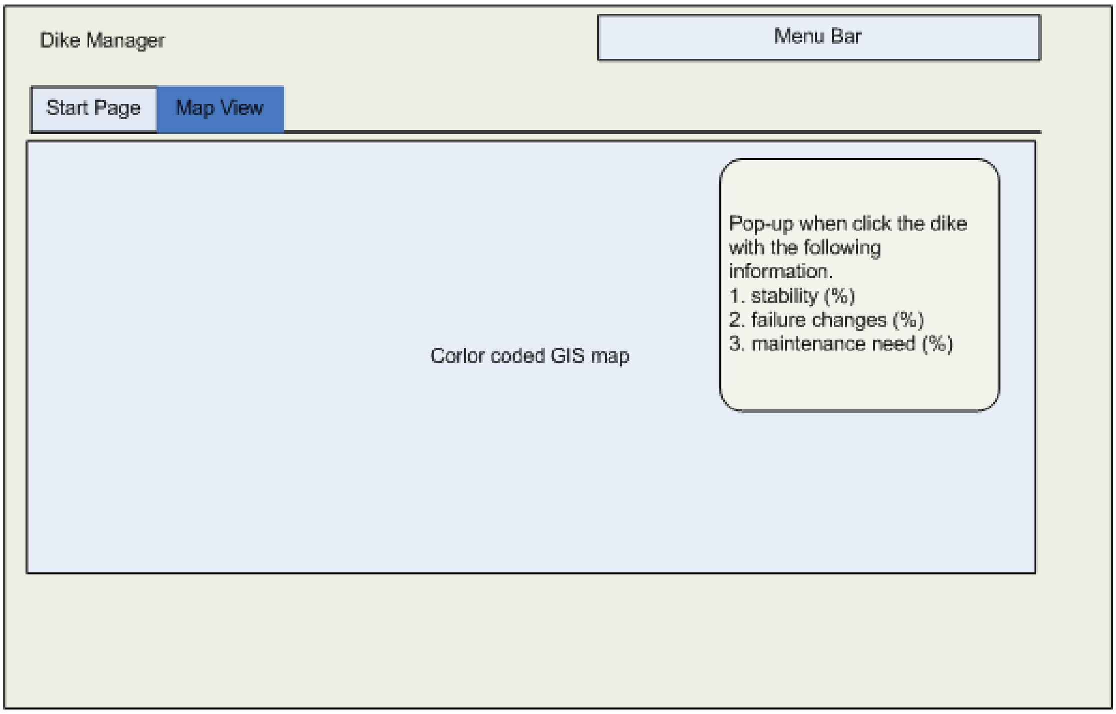


Figure 7-2: UI - Map View

Figure 7-2 shows the Map view for Dike manager. Dike manager uses this screen to orient the dike information with its geographical location. It contains a color coded dike map on top of the satellite basemap. When Dike manager clicks any of the dike block on the map, a pop-up will show the following information for that dike.

1. Dike Stability (in %)
2. Primary construction/asset details (made of clay, road on top, etc.)

When the levee is double clicked (or other mechanism) the user will be redirected to detailed levee page (only if time permits)

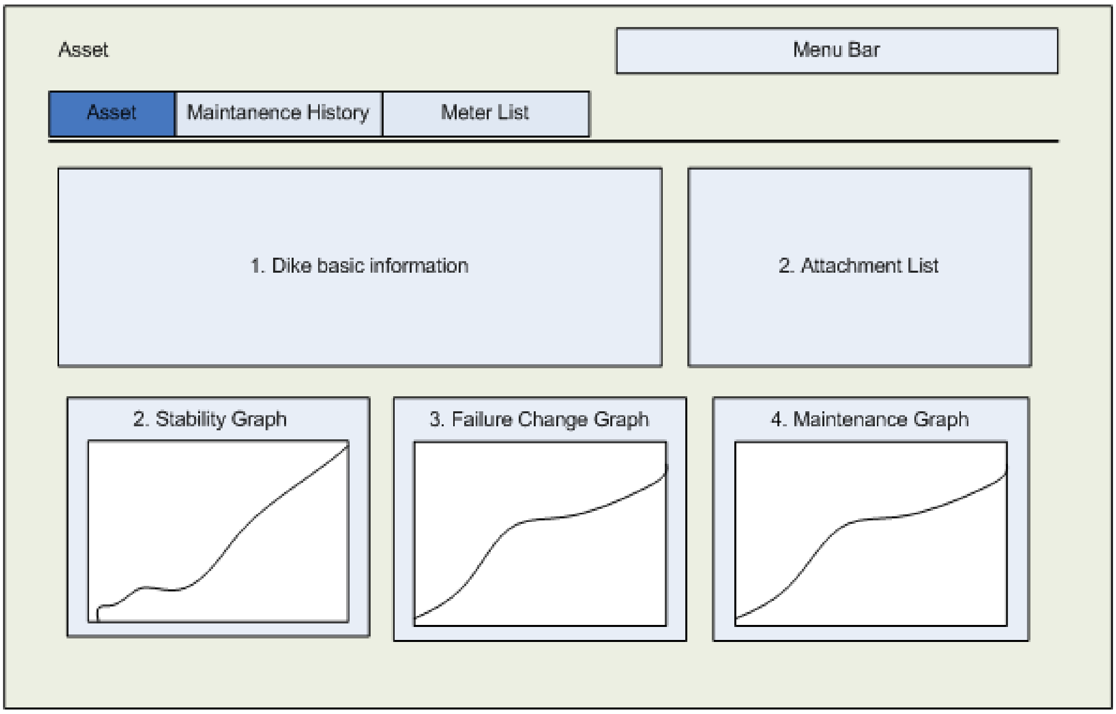


Figure 7-3: UI - Dike Asset Management View.

Figure 7-3 shows the dike management in asset view. Dike manager uses this screen to evaluate and start job plan for a specified dike based on the information observed. Each component on the screen is shown as below:

1. **Levee details:** Dike basic information shows the brief information for the specified dike. Fields such as the
   a) Levee attributes (length, width, construction).
   b) Levee specification (clay, sand. Peat).
   c) Levee description (What it is covered with at the front (stone), top (asphalt/road), land-side (grass))
   d) Attachment with construction schematics

2. **Inspection report:**
   a) Last inspection time
   b) Inspector name
   c) Attachment list with
      i. Inspect report (Word files)
      ii. inspection photos
3. Maintenance
   a) List of work orders (title)
   b) Date of work order initiation
   c) Date of work order execution
   d) Indication if work order is finished or open
   e) Description (maybe if you open work order details.
   f) Who will execute it (on details of WO)
   g) Attachment (photos of constructions, details)

4. **Stability graph:** Simple status message: good, average, bad. The following
   a) Assessed status: (only if dike manager has executed assessment.
   b) Forecasted status: whatever the forecast is

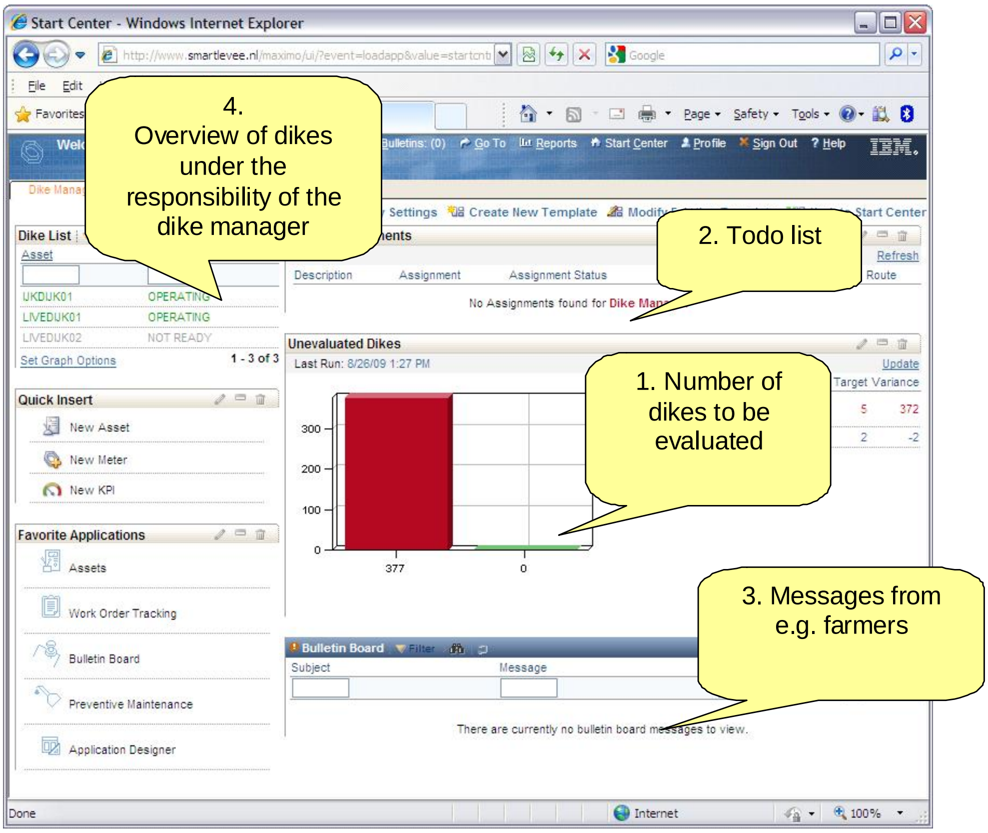
5. **Meters details**
   a) List of meter titles (type of sensor: temperature, etc.)
   b) Latest value
   c) If time permits create graph from latest 10 values.

6. **Assesment**
   Provides a function where the dike manager can change a value and enter a description with his personal assesment of the levee status. The story line is that the levee inspector
   a) Levee assessment: good, moderate, bad
   b) Description:

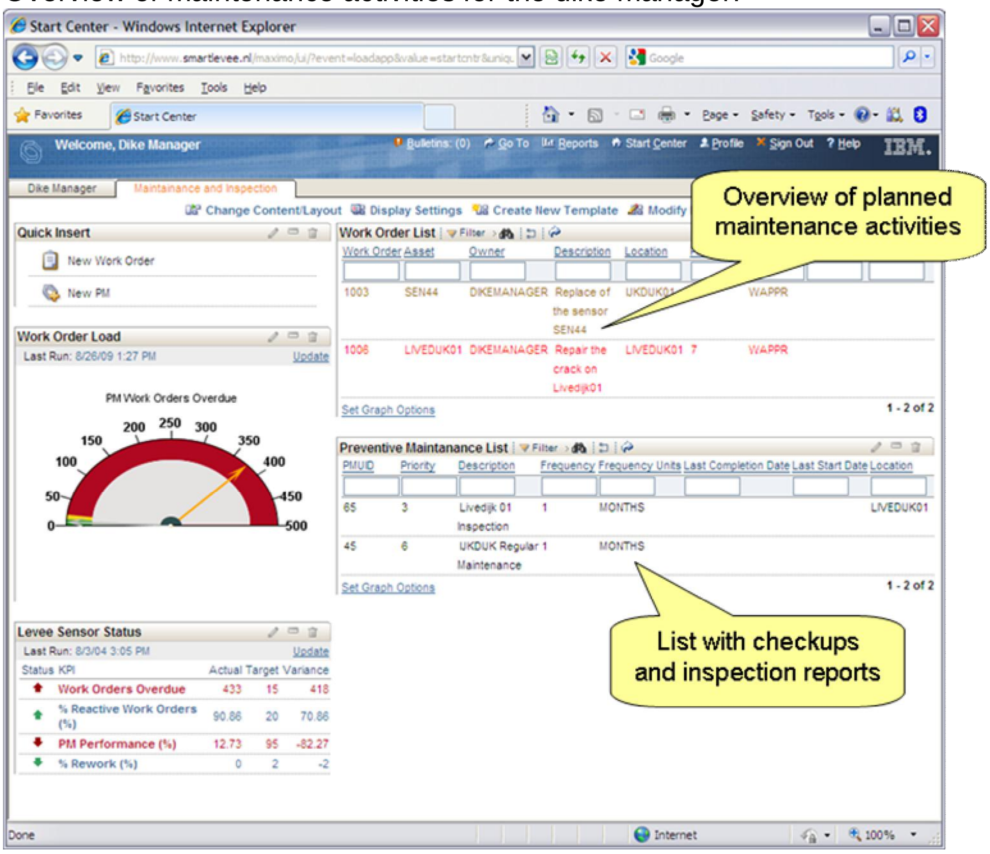
7.2.1 Screenshots Maximo

Below you will find several screenschots of the implemend Maximo interface. The screen shots are explained with notes.

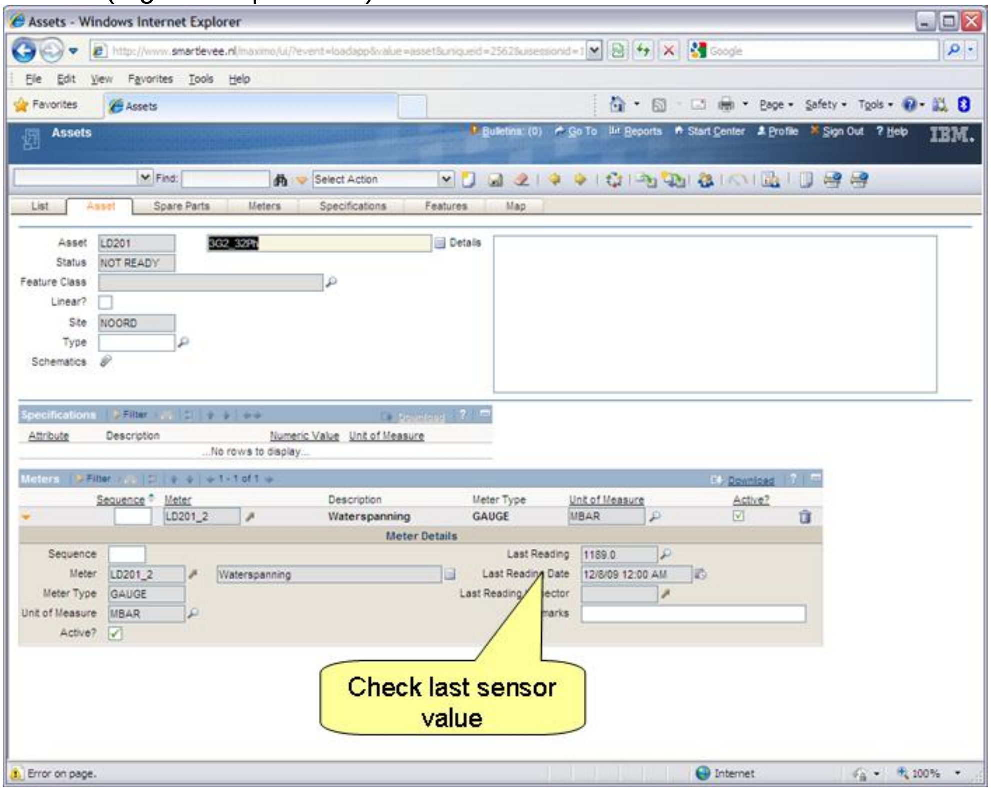
Dike manager's personal starting page:



Overview of maintenance activities for the dike manager:



Check the last known sensor values that are available for the dike mangers dike section (e.g. water pressure):



7.3 Roles: safety region, water boards etc.

For the implementation of the different roles in the water management chain as identified in this document a generic interface was developed which can be configured for a specific role.

A role, for example a safety region, can select (virtual) sensors which are available in the Flood control system. A map will point out on which geographic location the sensors are selected.

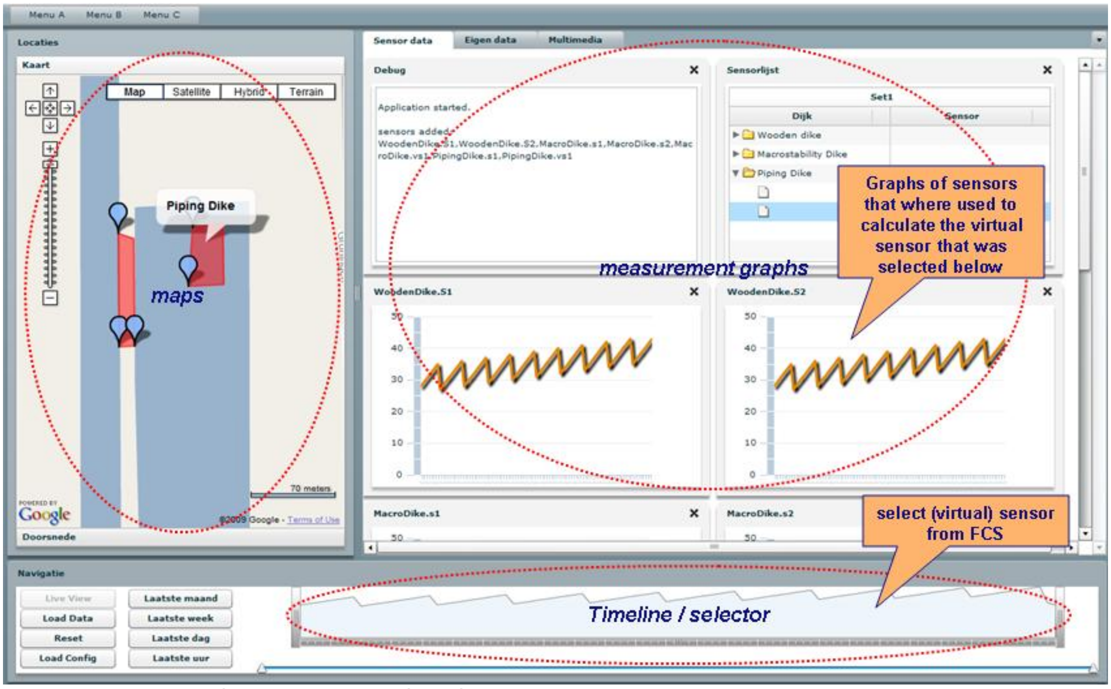


Figure 7-4: design for generic interface for various role in the water management chain

Figure 7-4 shows a generic interface design for various roles. The section "timeline/selector" refers to the timeline concept as explained in paragraph 2.3. The timeline enables users to branch sensor streams for different purposes e.g. simulation, alternation of sensor streams because of calibration correction etc. For every correction or simulation a new timeline will be created without loosing the original sensor data. Technically this is mechanism which is challenging to implement, within this project a start has been made to do so but is still subject to research in the future. e.g. The storage behind the timeline for the different versions and modification of the sensor data doesn't seem to map well on traditional relational databases.

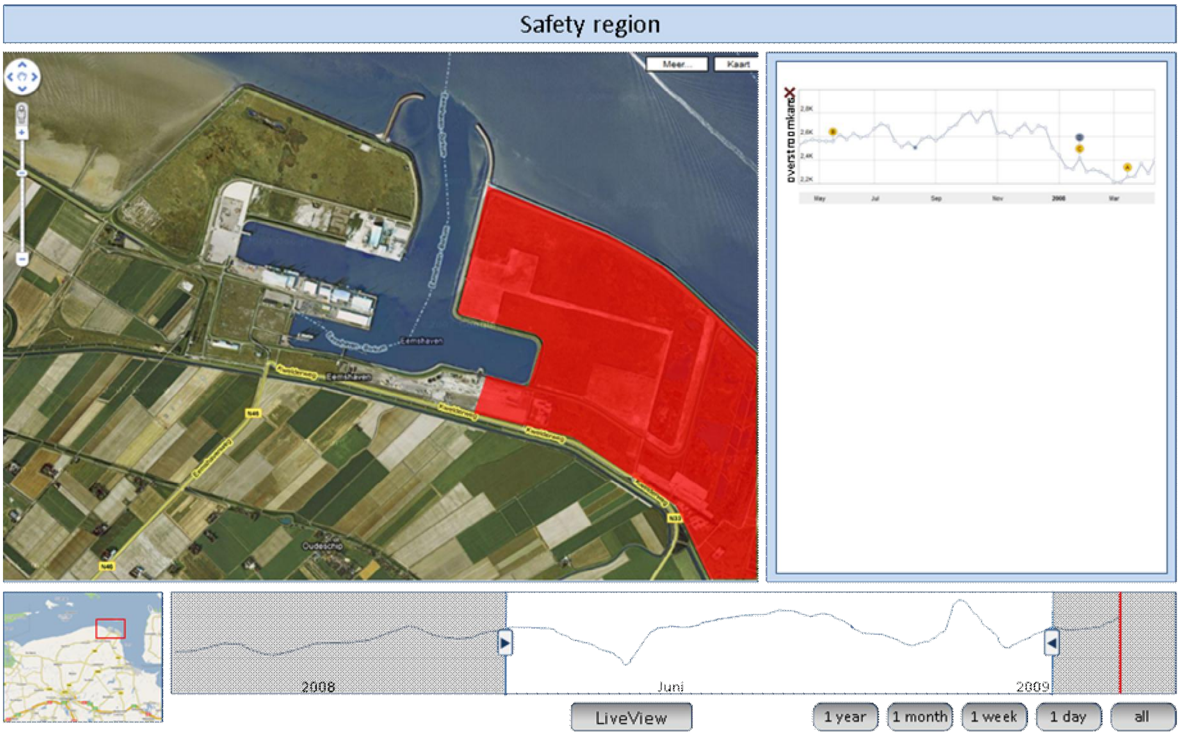


Figure 7-5: generic interface design, configured for the safety region role.

Figure 7-5 shows an example interface, build on the generic framework, for a safety region. A safety region will, in essence, have global overview of their area of responsibly. For example the virtual sensor 'flooding chance' can be selected. The timeline will give an overview of the development (and prediction) of the values of this sensor. Prediction functionalities are not implemented yet. Graphically the flooding change is expresses with coloured areas on a map.

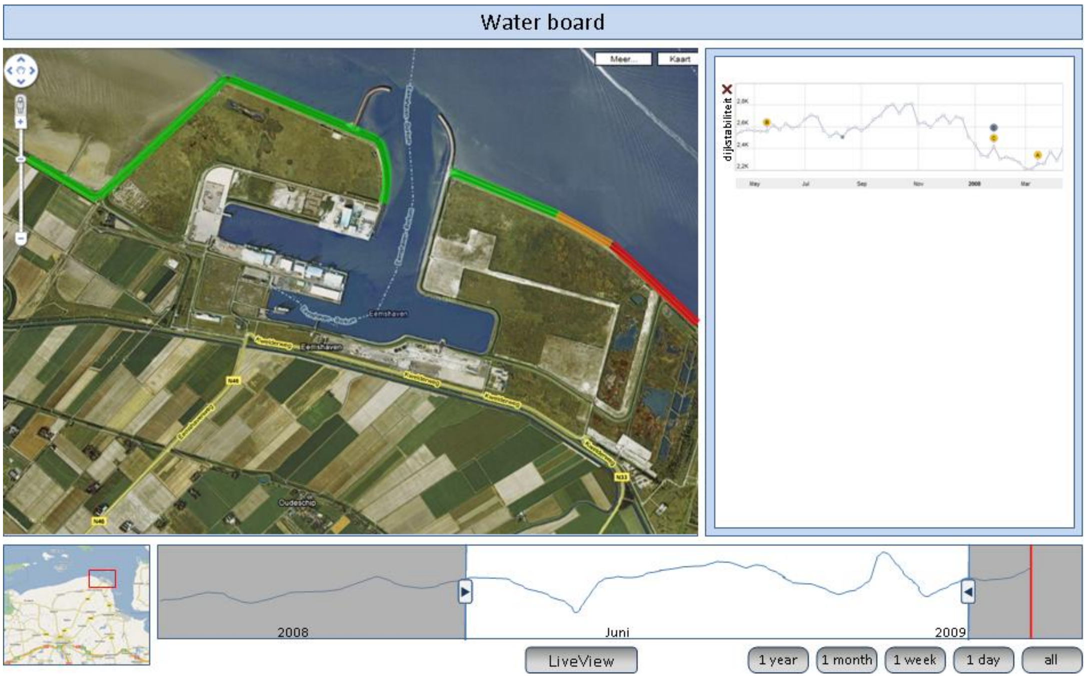


Figure 7-6 generic interface design, configured for the water board role

Figure 7-6 show an implementation of a visualisation for a water board on dike ring level. For each dike section the dike stability is indicated with a colour (green, orange, red) to provide a quick overview of the status in a certain dike ring area for which the water board responsible.

Appendices

Appendix: Additional scenarios

This appendix describes some additional scenario's complementary the chapter 4.

A number of scenarios are described to reach a common understanding of system behaviour, to design elements that support the required behaviour and to identify test cases. The scenarios consist of:
1. The robust flood control system.
2. High alertness on local level (fictitious).
3. Evacuation of Rivierenland 1995
4. 1953 flooding.

Scenario 1: the robust flood control system

Brief Description

This scenario describes a malfunction of part of a DMS. Some parts of the DMS are down or malfunctioning. The FCS detects the erroneous output and tries link with alternatives for its information needs. Even though some parts of the DMS are down, the FCS will still function, but the information is possibly less reliable. The FCS reports a lower level of reliability in chain of information, but is still providing the information required for decision making.

Actor Brief Descriptions

All primary stakeholders are involved, i.e. the dike manager, water board and province.

Preconditions

- Stable an normal dike situation.
- Some parts of sensor network are down or malfunctioning.
- Some of the sensors failing are located near the boundary with the area controlled by another water board.
- Multiple DMSes are part of the FCS.

Basic Flow of Events

1. DMS1 detects abnormal sensor values.
2. DMS1 checks if the sensor is malfunctioning by comparing the sensor values with the adjacent sensors.
3. Both adjacent sensors show normal values. DMS1 concludes that the sensor is malfunctioning or down.
4. DMS1 schedules a replacement and disables this sensor temporary for dike stability calculations.
5. The sensor is replaced and is functioning as it should.
6. The sensor is enabled again for dike stability calculations.

Alternative Flows

1. DMS1 detects abnormal sensor values near the border with DMS2.
2. DMS1 checks if the sensor is malfunctioning by comparing the sensor values with the adjacent sensors.
3. DMS1 requests sensor data of the dike segment of DMS2. It uses these values to determine if its own sensor is malfunctioning.

4. Both adjacent sensors show normal values. DMS1 concludes that the sensor is malfunctioning or down.
5. DMS1 schedules a replacement and disables this sensor temporary for dike stability calculations.
6. The sensor is replaced and is functioning as it should.
7. The sensor is enabled again for dike stability calculations.

Scenario 2: high state-of-alert on local level

Brief Description

This scenario describes a high state-of-alert situation due to a local gale. Only the dike manager is involved. The gale is not of a level of severity that requires the water board to act.

Actor Brief Descriptions

Two primary stakeholders are involved, i.e. the dike manager and the water board. No secondary stakeholder require information from the FCS.

Preconditions

Stable, normal dike situation.

Basic Flow of Events

1. Due to the storm and the wind direction the water level rises.
2. The water level rises higher than expected. The status of the DMS is changed to a higher state-of-alert level.
3. Due to the higher state-of-alert level, the monitoring system responds by increasing the sample frequency.
4. The DMS is monitoring the water level at a higher sample rate. No critical water levels are reached. The dike stability remains on a normal level.
5. The water level drops.
6. The DMS responds by changing the state-of-alert to a lower level.
7. The DMS responds by decreasing the sample frequency of the monitoring system.

Post-conditions

- Stable dike situation.
- The water board was not notified about this local incident. The DMS increased it alertness, but conditions did not become critical. The incident is logged with all relevant data.

Scenario 3: Evacuation of Rivierenland 1995

Brief Description

At the end of January 1995, the water level in the rivers Waal and Rijn/Lek rises above a critical level. The dijkgraven of the water boards cannot guarantee the stability of the dikes any longer. With that, the safety of the people in Rivierenland, the region between the two rivers, is at stake. A regional coordination centre (RCC) is formed. The decision to evacuate Culemborg and Tiel is made, based on incomplete information. After that, the water levels fall. The dikes did not fail and the people can return to their houses. The scenario corresponds to alert level 1 (regional decision making).

Actor Brief Descriptions

Primary: various dijkbeheerders, 3 water boards, Province Gelderland, Rijkswaterstaat,
Secondary: municipal administrations of Culemborg, Tiel and other towns, police, fire department, media (radio, kabeltv, regional TV broadcaster), companies, farmers, citizens.

Preconditions

Stable dike situation, with rising water levels in rivers Lek and Waal. The water levels rise to a point where the water boards cannot guarantee the stability of the dike any longer.

Basic Flow of Events

1. The use case begins when a regional coordination centre (RCC) is formed at the provincial government building, in contains the Commisaris van de Koningin, mayors, representatives of water boards, Rijkswaterstaat, police and province of Gelderland.
2. The decision is taken to evacuate Tieler and Culemborgerwaard (31 January). Too many people who were not directly responsible for the decision, interfered in the decision making process.
3. Because of a malfunctioning fax machine, a message about deteriorating conditions of a dike did not reach the RCC. The polderdistrict had started taking measures, based on their fax. The decision about evacuation had already been taken.
4. People are informed about evacuation, by letter. The editorial staff of the Kabelkrant had already left the area, so “old” news is repeated which caused confusion among the people. The editorial staff cannot be reached.
5. Exemptions on entering the Rivierenland area were made based on different criteria in different towns.
6. Police regulated traffic, but no traffic plans were available. Jamming of roundabouts in Culemborg.
7. During evacuation in Tiel, there is a sudden threat of dike failure in Ochten. The Mayor decided that an emergency evacuation of Ochten was necessary, which claims evacuation capacity in Tiel. On advice of the police and fire department, evacuation in Tiel is temporarily stopped. Ochten is evacuated.
8. Weather conditions change and water levels drop. The threat of dike failure falls away.
9. The RCC takes a decision concerning the return to Rivierenland. The RCC wanted to prepare for the return of people by first letting return emergency services, general practitioners, municipal workers, housing agencies and shop suppliers.
10. Minister Dijkstal of Internal affairs reports on TV that it is safe to enter Rivierenland again without consulting the RCC. By interference on national level, the preparation for the return of citizens was not ready when the people returned to their houses.
11. People return to their houses without traffic jams.
12. A lot of information has to be gathered to evaluate the events.

13. The use case ends.

Post-conditions

Stable dikes, people returned to the area and a lot of lessons to be learned.

Scenario 4: 1953 Flooding

Source: http://www.bbc.co.uk/weather/features/understanding/1953_flood.shtml

Brief Description

This scenario is modelled after the 1953 flooding where a combination of exceptional weather conditions and spring tide caused devastating effects along the shore of Eastern England, Belgium and the Netherlands. Many people lost their life in this event: 300 in England, 30 in Belgium, 1800 in the Netherlands. Nobody had been warned although forecasts were available. This was caused by organisational issues (no central responsibility) and failing technology (radio stations didn't broadcast at night and the phone line had been broken by the storm).

In this scenario, the flow of events is described for a situation similar to the 1953 circumstances, but with the availability of a FCS. As a starting point for this scenario. the storm surges on the North Sea move water up the coast. Additionally, high volumes of melting water are flowing down the inland rivers causing potential inland flooding. The events are detected by sensor and forecasting systems. A levee breach in Germany near the border will cause flooding in the Netherlands. International exchange of detailed information on the progress of the flooding is crucial to help the emergency services. Because of the spring tide and storm surge at sea, the water of the rivers can not be fully discharged at Rotterdam. Flood maps indicate major flooding in the Rotterdam area.

The FCS makes sure that the governmental departments work together and make decisions based on the same information. The public is warned and evacuated in time. In addition other countries are warned and forecast are compared to gain maximum understanding of the event which leads to improved resolution of forecasts as to where and when the storm will hit the hardest. Emergency counter measures will be implemented to minimize damage.

This scenario initiates the highest crisis level available and includes international cooperation on flood control.

Actor Brief Descriptions

In a real crisis many more actors are involved and their roles and responsibilities are more complex than described here. The purpose of this scenario is to indicate the various roles and different handling of information, but not the details.

National level:

- Crisis organisation (in the Netherlands the DCC) to coordinate crisis between governmental departments
- Ministers of
  - Internal affairs, responsible for safety of people
  - Foreign affairs, responsible for warning of foreign countries

  - Transport, Public Works and Water Management (in the Netherlands represented by the Waterdienst / Water Management Center Nederland), responsible for getting the right information to the ministers and the public.
  - Prime minister.
- Weather service (in Netherlands KNMI) to provide forecasts.

Regional level:
- Major to take evacuation decision
- Regional offices for water management (water levels and alerting, in the Netherlands implemented by Rijkswaterstaat regional offices and HMC's?)
- Maintenance of levee to supply latest information on strength of levee (water boards) by inspection team and historical analysis
- Emergency services like fire department, medical care and the army

Public
- Public will receive an SMS on their mobile in order to evacuate

Preconditions

- Current Dutch situation:
  - stable dike situation
  - high economic value on west coast
  - high population density on west coast.
- Current English East Coast situation:
  - ?
  - ?

Basic Flow of Events

1. Weather and water modelling applications predict storm surges. The FCS will send out and visualise an alarm.
2. At the same time the river water levels rise above the critical point. The FCS will send out and visualise an alarm.
3. The crisis team gets together and identifies the potential flooded areas. These are Rotterdam the east coast of England and the border of The Netherlands and Germany. A specific alarm is send to these areas. The FCS dashboard will 'reconfigure' itself to show levee strength of all these areas based on sensor systems.
4. The levee inspectors are now in the field inspecting the status of the levee confirming their findings in addition to the sensor readings.
5. The Major of Rotterdam consults the FCS and sees the status of the levee as critical and a countdown timer. The FCS will also show important messages waiting (?) and the status of all emergency services (# ambulances, # fireman), a real-time flood map and the script for evacuating.
6. Based on the information of the FCS, the Major decides to evacuate certain areas. The progress of evacuation is monitored by FCS.
7. When the levees collapse part of the sensor infrastructure will fail. This is visualised and for that area the system will switch to a forecasting mode. An indicator will show the reliability of the results.
8. The English, Dutch and German system will show up different forecasts that can be compared. Based on this comparison the forecasts will be further refined.

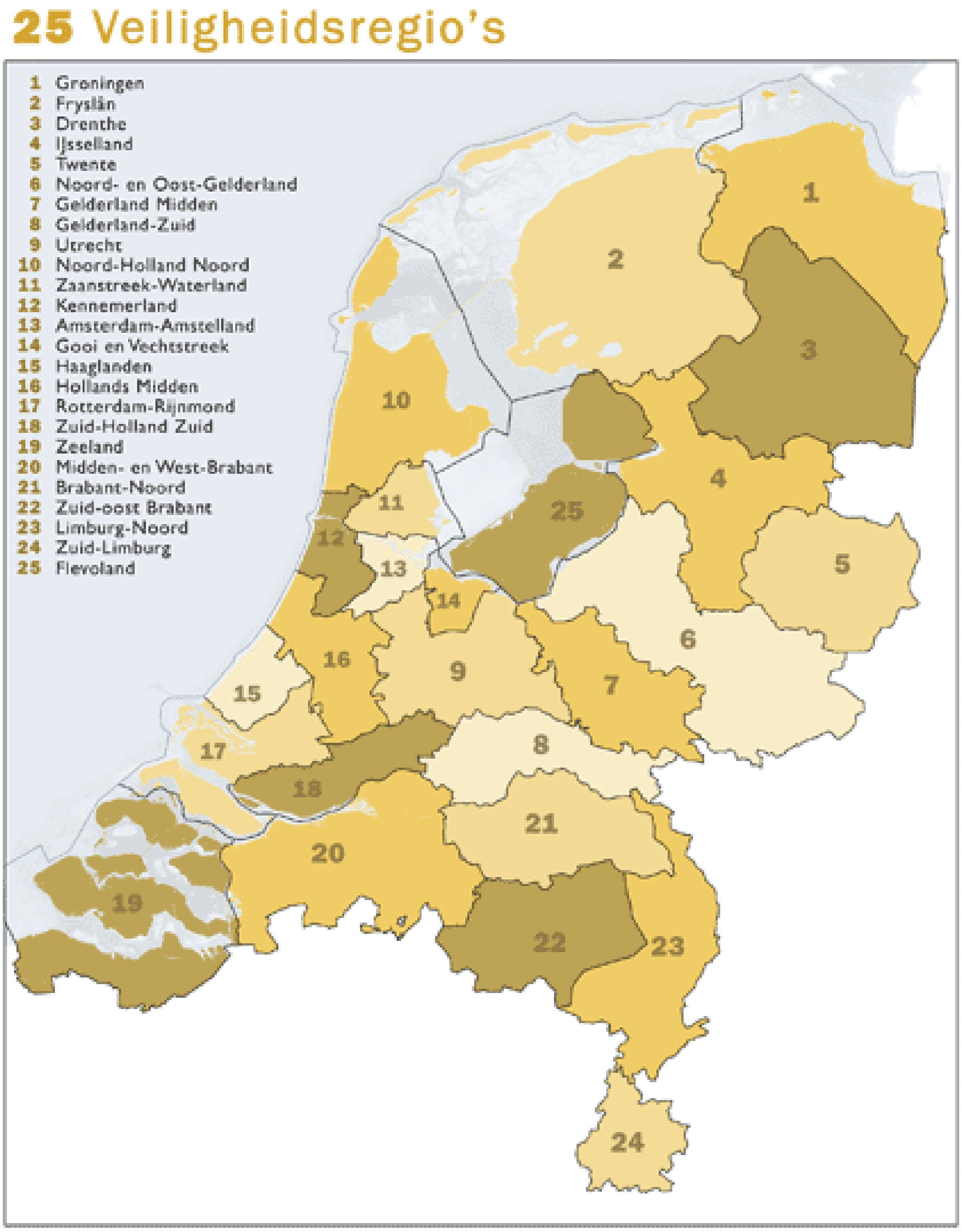
9. When the flooding occurs, the number status of emergency services is updated with latest information.

Post-conditions

The dike has failed.
The people have been evacuated.

Appendix: safety regions in the Netherlands

The Netherlands is divided in 25 safety regions in order to maintain public order and safety. More information can be found on Wikipedia, http://nl.wikipedia.org/wiki/Veiligheidsregio



Appendix: Dikering in the Netherlands

Source: Wet op de Waterkering, bijlage I


Bijlage IA, als bedoeld in artikel 2,
eerste lid, van de wet op de waterkering
Dijkringgebieden langs de Maas ten zuiden van Nijmegen
41
36a
36
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
91
92
93
90
94
95
Legenda
dijkringgebied, omsloten door primaire waterkeringen dan wel hoge gronden
80 nummer dijkringgebied
hoge gronden
grens Nederland
Kaartbewerking: Rijkswaterstaat,
Dienst Weg- en Waterbouwkunde, no 1

Appendix: User-Centered Design process

The method used for designing the user interface is the User-Centered Design process (source: http://www-01.ibm.com/software/ucd/ucd.html)

User-Centered Design (UCD) is an accepted industry approach for designing applications that are highly usable by their target audiences, allowing users to perform their intended tasks efficiently and as simply as possible.

High lights:

- Provide a high quality, user-centered design
- Provide an ergonomically efficient design
- Provide a design that meets your business goals
- Iterate and evaluate frequently during design

Tasks:

1. Provide a human-focus by bringing business goals and user needs together through appropriate user interface design
2. Provide an increased emphasis and expertise throughout the development of the user interface to ensure that users will be more satisfied and more productive with the final application
3. Gather requirements and create user profiles
4. Analyze and design user interfaces including information design, interaction design and visual design
5. Conduct usability tests including reviews, user walkthroughs and formal usability testing
6. Apply user centered design (UCD) principles to provide guidance and expertise for developing solutions and producing work product deliverables to enhance their usability

The purpose of the UCD method is to:

- Improved Customer Satisfaction
- Increased user Productivity
- Reduced Development Time and Cost
- Reduced Support Cost
- Reduced training time and cost

The UCD process steps and related work products are shown in the next figure:

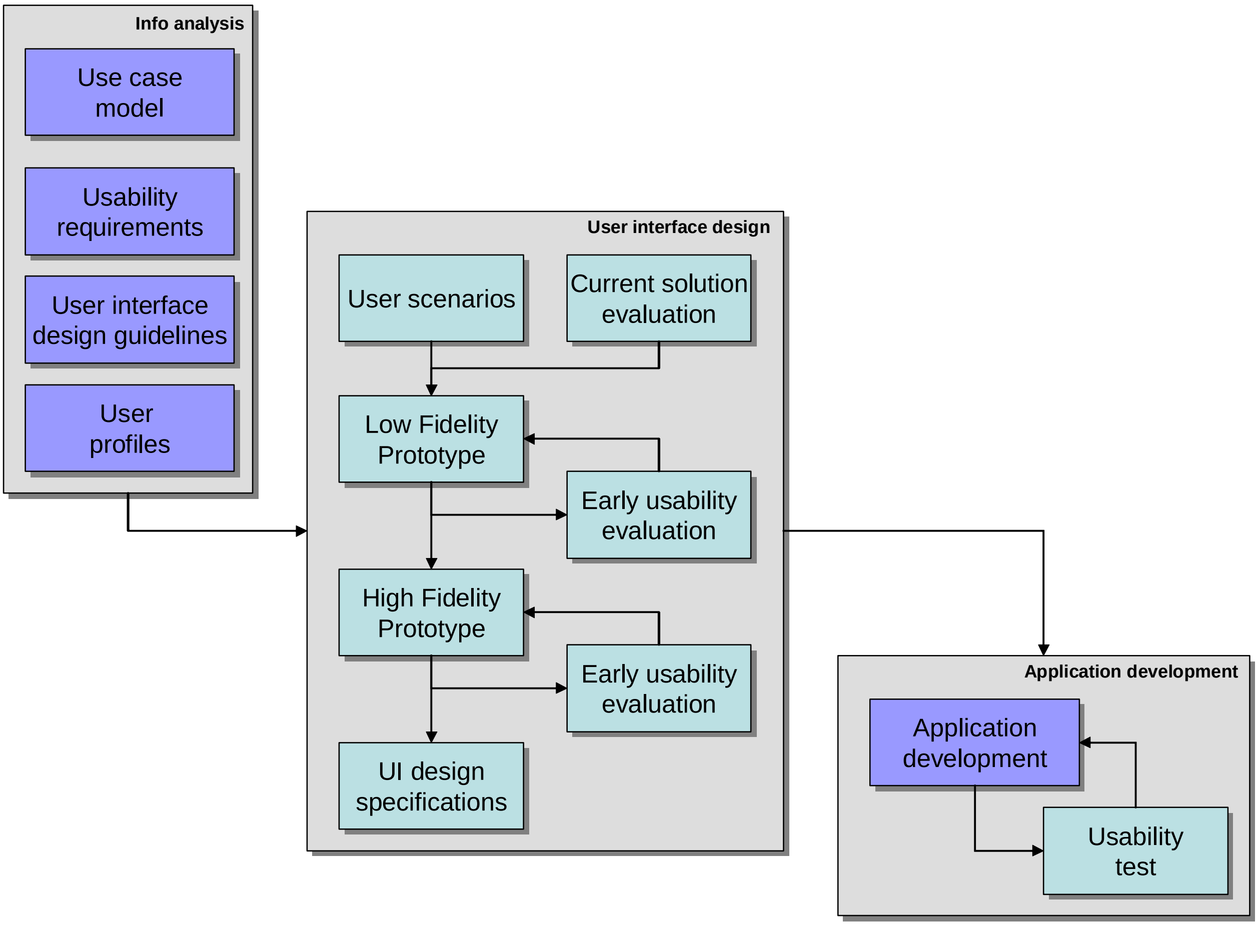


Figure 0-1: User-Centred Design process

Appendix: Definitions Usability Attributes

Usability Requirements contain measurable user specifications of these generic attributes applicable to the new system. These include:

Who: The users to whom the particular requirement applies, including users who have disabilities.

Preconditions: Context of the measurement of the attribute, including access to other software, job aids, and user assistance

Constraints to be considered: Such as hardware and personnel, including assistive technologies.

Environment: Such as noise level and interruptions

Performance Criteria: Measurable actions, such as outputs, task success, accuracy, errors and assists, time on task, and user satisfaction.

Interaction Attributes

Tailorability: The interface and its components can be customized to suit the user's requirements, allowing for optimization based on work style, personal preferences, accessibility (such as font size, zoom, display layout, system settings, and color choices), and experience level.
Efficiency: The product minimizes task steps, simplifies operations, and allows for tasks to be completed quickly. Efficiency should be compared whether using keyboard, mouse, or assistive technologies by user with disabilities.
Integration: Tasks that cross functional boundaries are executed automatically where possible or can be easily performed by the user manually if required. The integration of manual processes and notification to execute manual processes should meet accessibility requirements.
Navigation: The user is able to develop an accurate mental map of the product's structure. At any point during the task, the user is aware of the current interface "location" and knows in which "direction" to proceed.
Predictability: All selections, actions, and operations lead to outcomes that are expected by the user.
Conceptual Integrity: The user has a clear, consistent conceptual model or metaphor that simplifies product learning and task performance.
Consistency: All selections, actions, and operations behave in a common fashion and are in keeping with standards.
Tolerance: The solution is designed to minimize the consequences of user error and provide recovery options, and is able to adapt to different work styles. If the user has assistive technology, tolerance levels should be configurable according to the user's workstation accessibility requirements.
Feedback: Appropriate information is provided to indicate progress of operations, confirmation of actions, input restrictions, errors, etc. The feedback output devices and instruction should meet accessibility requirements.
Responsiveness: The solution responds quickly and seamlessly when interface objects are selected, activated, or moved. Actions and operations are completed quickly. If manual intervention is required, the responsive inputs should meet accessibility requirements.
Adaptiveness: The solution dynamically changes its appearance, behavior, and structure to best support the task and specific user requirements due to disability or environment. User actions are anticipated by the product to facilitate automated sequences that reduce task steps and/or user effort. Additionally, there should be

conditional adaptiveness to include involuntary user actions.
Goal Facilitation: The solution is organized; so that its operation enables the natural sequence of steps the user can follow to perform the task.
Learnability: The system enables users to easily accomplish basic tasks the first time they encounter the solution.
Memorability: The solution enables users to re-establish proficiency quickly and easily when they return to it after a period of not using it.
Errors: The solution minimizes the number of errors user make and enables them to easily recover.
Satisfaction: The solution provides a high level of satisfaction.

Display Attributes

Attribute/Description
Recognizability: Display elements (and accessible alternatives such as meaningful alternative text) are identifiable, clearly presented, and are distinguishable from one another.
Comprehensibility: Display elements are intelligible. The user is able to understand the meaning of terminology, graphics, sound, and other components of the product interface. The graphics and sound should have assistive text or documentation to convey the comprehensibility.
Cueing: The product display provides indicators to denote the state of the task and the product, and to suggest appropriate actions.
Affordance: The design of display elements makes their purpose and operation apparent to the user.
Layout: The positioning of display elements is logical (including the keyboard tab order), appealing, and enhances task performance.
Consistency: Display elements have a common “look-and–feel” and conform to standards.

Affective Attributes

Attribute/Description
Character: The solution has a unique, congruous design that distinguishes it from its competitors and gives it a recognizable “personality,” yet is still compatible with assistive technologies and system settings.
Aesthetic Appeal: The interface incorporates color and balance and other aesthetic characteristics in a way that is pleasing to the senses, yet does not create accessibility barriers to any group of users.
Control: The user feels in control of the solution and is able to perform tasks with confidence using his or her preferred choice of input.
Engagement: The user becomes absorbed in the task while using the solution; the solution focuses the user’s attention, minimizes peripheral distractions, and decreases awareness that time is passing.
Delight: The solution interface is perceptually and intellectually stimulating. The design takes advantage of humor, surprise, and other elements that excite the mind and senses to make the task more enjoyable.

Accessibility Attributes

Choice of input methods: The solution supports the user’s choice of input methods including keyboard, mouse, and compatibility with voice and assistive

devices. The primary desktop/user interface requirement is to provide keyboard access (mouseless operation) to all features and functions of the application. The operating system, browser/player, and assistive technology may also provide some of the input methods.
Choice of output methods: The solution supports the user's choice of output methods including display, sound, print, and compatibility with assistive technology such as text-to-speech and Braille displays. The primary desktop/user interface requirement is to provide text labels for icons, graphics, controls, and other user interface elements and to support visual indications for sounds. Using standard operating system controls and interfaces compatible with assistive technologies – and implementing the accessibility APIs (e.g., Java Accessibility, Microsoft Active Accessibility, etc.) for customized interfaces on the target platform - will help meet this principle in a way that will be usable for people with disabilities.
Consistency and flexibility: The solution respects the user's choice of system behavior, colors, font sizes, keyboard, and other system settings.

Appendix: Decision process (OODA loop)

We have adopted the principle, that the decision process is a cycling process, where actions will have a (positive) impact on the actual situation. In other words, the result of each action will used as input of a next execution of the cycle.

We have used John Boyd's decision cycle as the base to classify all activities. This decision cycle was first used in warfare and later adopted by other decision processes. The OODA loop is defined as follows:

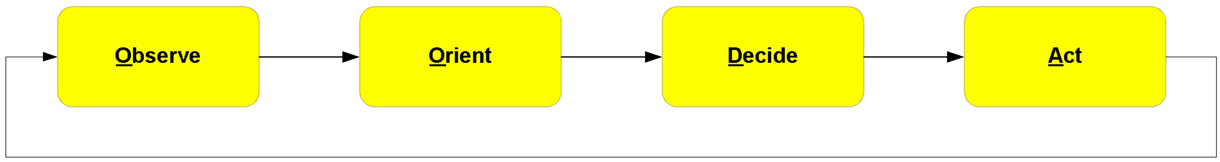


Figure 0-1: The OODA loop

The OODA loop types of activities will be explained below.

Observe

Collect and Store: Data, Signals and Information, i.e. the collection of data/information by means of sensing. Examples are gathering information about levee strength, water levels and weather conditions

Orient

Where data/information/signals are analyzed and interpreted. This process is about making sense of what the data/information/signals are about. Examples are modeling levee strength or river flow resulting in its understanding.

Decide

Determination of a course of action and based on the interpretation of the data/information/signals.
It can be a measure that needs to be taken or a policy that needs to be implemented. Examples are evacuations or temporary levee reinforcement.

Two sorts of decisions can be distinguished;

- Strategic decision:
  These decisions are only taken on an interregional or national level. They have enormous consequences. Examples are the decision to start an evacuation and large scale measures such as inundating an area. These decisions are made by the strategic level and are advised by the tactical level.
- Tactical decision:
  These decisions can be regional or interregional. They can be routine or non-routine. Examples are local measures, such as supporting levees with other material like sand and sandbags. These decisions are made by the tactical level. The strategic level can be informed about this if needed.

Act

Act is where decisions are transformed into actions. In case of flooding this means that measures need to be taken (unless it is decided to not take a measure). Examples are placing sandbags or blocking off roads.

In general a single decision, in a complex environment, will be transformed to many actions. All these actions should be coordinated and monitored during execution. Hence coordination and monitoring are important activities.

Many times these actions are already defined and document as procedures. Defining these procedures is part of the preparation theme.

There are different types of actions:

- Large-scale actions:
  These actions relate to strategic decisions. Huge measures such as inundating an area can be considered a large scale action.
- Small-scale actions:
  These actions relate to tactical decisions. Smaller and less far fetching measures, like repairing a part of a levee can be considered as a small-scale action
- Operational actions
  These actions relate to real doing things, like placing sandbags or actions to repair a levee. These actions are not part (yet?) of the reference architecture.
- Recognized mechanisms

Certain people or organizations need to make sure that others or even the complete chain functions well. Three types can be identified:

- Inter-regional or national coordination:
  This is coordination on an inter-regional or national level. DCC is, for example, the responsible actor in the water column.
- Regional coordination:
  This is coordination on a regional level. The safety regions are a good example of this.
- Local coordination:
  This is coordination on an even less high level. The coordination of a group of levee patrollers can be considered 'local coordination'.

Inform

Within the decision cycle, information is passed from one activity type to the following:

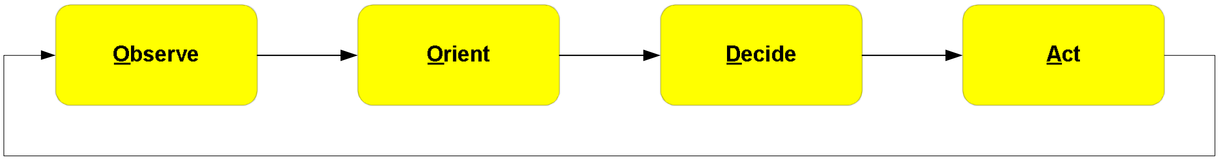


Figure 0-2: The OODA loop

This information is provided by people and organizations. Information sharing occurs on all levels, although it depends per level how detailed the information is going to be and to what region it applies. The higher, the less detailed the information will be and the more it applies to a bigger region.

In case information is not complete, not valid or inaccurate to complete the activity, alternative sources of information should be used, or an action should be issued with a request for specific information. This will lead to a new execution of the cycle.

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