Ringtoets Requirements and Design

Keywords

Summary

Ringtoets is the provisional name of new software for the compulsory safety assessment of the primary Dutch flood defences (dike rings). Ringtoets will support the new Dutch regulations, called VTV-2017 (*Voorschriften Toetsen op Veiligheid*). These regulations will introduce a new assessment level, based on the failure probability of a dike ring. The probabilistic method required for this purpose will also be used to calculate characteristic water levels, to calculate characteristic overtopping levels, and to calibrate the required safety factors for a traditional deterministic assessment, per dike section and failure mechanism.

Version 1.1 of this document contains the final specification of the functional and non-functional requirements for Ringtoets, together with a third draft of the functional design and a second draft of the technical design. The content is based on input and response from an advisory group, consisting of representatives from regional water authorities and consultants.

The introduction and requirements are contained in chapter 1 to 3. Chapter 1 describes the context and background. Chapter 2 describes the scope and the tentatively supported workflow. Chapter 3 lists the functional and non-functional requirements, including priority indications. The Waterdienst has formally approved the final content of these chapters in April 2012. This content is therefore closed for further discussion since version 1.0.

Chapter 4 (Functional Design) translates the workflow and requirements to so-called use-cases, describing the interaction between the user and Ringtoets, during different workflow steps. Chapter 5 (Technical Design) translates the use-cases to a more detailed technical description of screens for the different activities, and to the data-model underneath. Compared to version 1.0, chapters 4 and 5 contain the result of a review of version 1.0, in the course of June 2012. Additionally, these chapters contain further improvements, following from the preparation and execution of three actual implementation stages between September 2012 and May 2013. Continuous further improvement during future stages is part of the development strategy.

References

Masterplan WTI-2017. Deltares report: 1201617

Version	Date	Author	Initials	Review	Initials	Approval	Initials
0.1	Oct 2011						
0.2	Dec 2011						
1.0	June 2012						
1.1	May 2013	Marcel Visschedijk Robert Kamp Rob Brinkman	[signature]	Kin Sun Lam	[signature]	Jan-Aart van Twillert	[signature]

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final

Contents

1 Introduction

1.1 Ringtoets

Ringtoets is the provisional name of a new software system for compulsory safety assessment of the primary Dutch flood defence systems (dike rings), according to new Dutch regulations called VTV-2017 (*Voorschriften Toetsen op Veiligheid*). Ringtoets connects for the calculation of failure probability to separately defined software, called *Hydra-Ring.*

1.2 Purpose and scope of this document

The document in hand defines the functional and non-functional requirements for Ringtoets, as well as the functional and technical design.

- First purpose of this document is to allow the principal to check if both the requirements and the functional design are according to expectations. The purpose of intermediate versions of the functional requirements and functional design is also to gather and use feedback from the Ringtoets Advisory Group. This group consists of both the regional water authorities responsible for assessment and the consultants to which assessment tasks are usually delegated.
- Second purpose is to provide the Ringtoets developer with all required information for implementation, testing and (future) maintenance. Especially the technical design in chapter 5 serves this purpose.

For a description of the new VTV-2017 assessment procedure, the reader is referred to the first framework description [Lit 6.6]. For a description of the requirements and the design of the probabilistic part, the reader is referred to the Hydra-Ring design document [Lit 6.2]. For the scientific background on the implemented methods and algorithms in the probabilistic part, the reader is finally referred to Hydra-Ring's scientific documentation [Lit 6.1].

1.3 Status and process

Version 0.2 (December 2011) contained already a second draft for the requirements (chapters 1 to 3) and a first draft for the functional design (chapter 4). This version has been discussed with the Advisory Group on March 30, 2012. After that, all received feedback from the principal and the advisory group has been discussed with the principal on April 10, 2012. This discussion has resulted in agreement on the required modifications to the chapters 1 to 3 [Lit 6.13].

Version 1.0 (June 2012) contained the amended final requirements, together with a second draft of the functional design and a first draft of the technical design. Version 1.0 served also as input for the first development period in September 2012.

Version 1.1 contains an update of both the functional and technical design (chapter 4 and 5). This update reflects the new insights, gathered during the first three development stages, up to and including April 2013. The update also reflects all received feedback from the principal and the Advisory Group. Further improvement will take place during the following stages of development.

1.4 Background

1.4.1 WTI-2017 project

Rijkswaterstaat has commissioned Deltares to develop a new set of methods and tools for assessing and designing the Dutch flood defence systems based on the failure probability of a dike ring. Since 2012, this development is a part of the project WTI-2017 [Lit 6.11]. A first version of the new regulations and supporting software needs to be available in the course of 2013, in order to start an evaluation and improvement period that will run until the end of 2016.

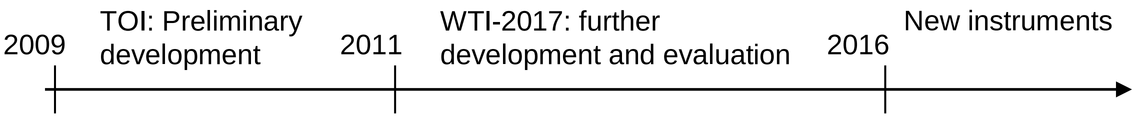

Figure 1.1 Global time schedule TOI project

Figure 1.2 presents a sketch of the view of Rijkswaterstaat on the context of the assessment instruments. The figure originates from the TOI Project Start Architecture document [Lit 6.7]

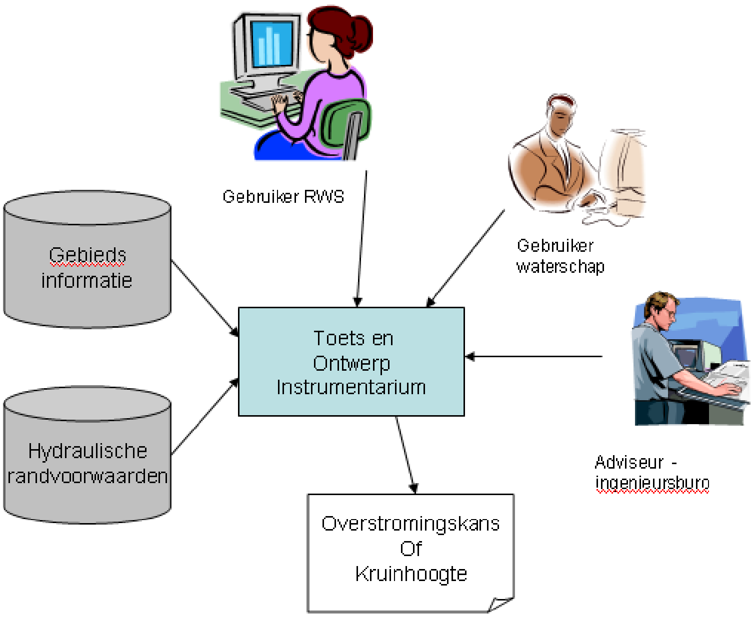

Figure 1.2 Rijkswaterstaat view on system context, according to [Lit 6.7]

Figure 1.3 shows the shared failure mechanism and UI libaries for WTI dike assessing and designing tools. Shared libraries allow for generic tool development and implementation, which fits into the Rijkswaterstaat's vision to optimize the total support and maintenance costs of software applications.

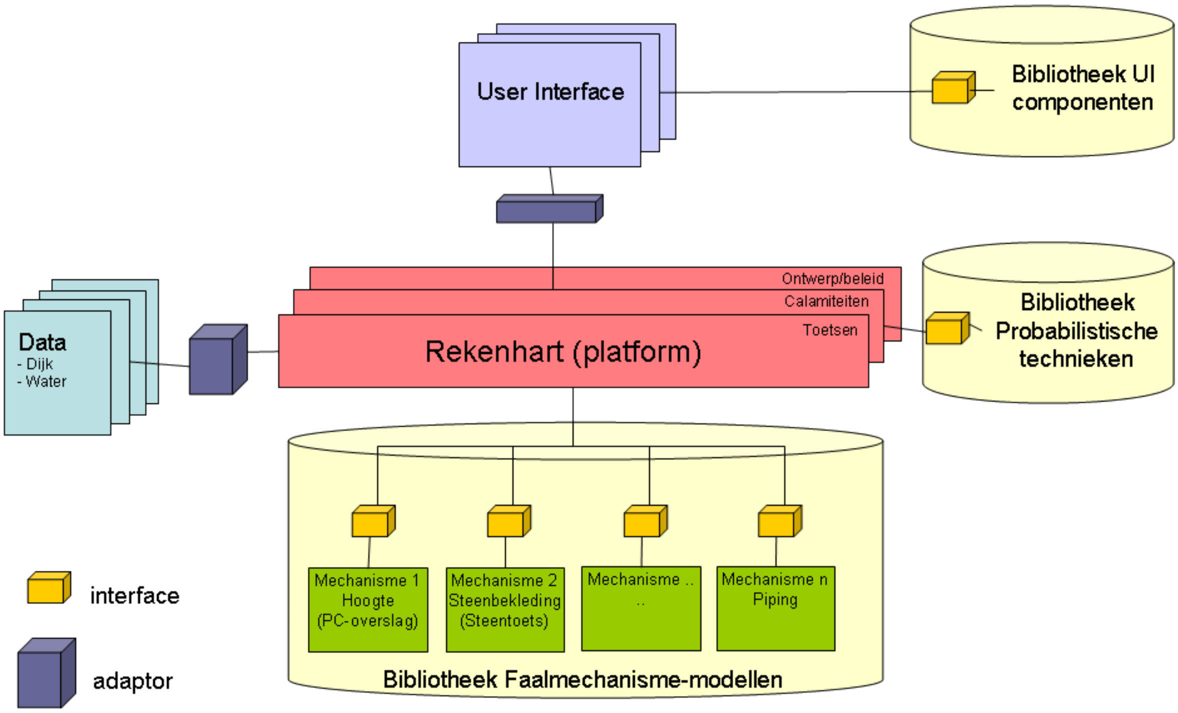

Figure 1.3 Shared libaries for WTI dike assessement and designing tools

1.4.2 Assessment method according to the VTV-2017

The current set of regulations (VTV-2006) and supporting set of software (Hydra's, Steentoets, Grastoets, Golfklap, D-GeoStability/MStab, Duros etc) is based on a partly *probabilistic* and partly *deterministic* safety assessment of dikes, dunes and structures. The Hydra software determines first in a probabilistic fashion the water level, wave parameters and overtopping characteristics per cross section. Further assessment for other failure modes (mechanisms) is executed per failure mode and per section, using a characteristic water level with allowed exceedance frequency (*toetspeil*) as calculated by the Hydra's. After an initial relevance check (level 0), a simple assessment by a decision rule (level 1) can be followed by a detailed assessment (level 2). The simple assessment usually requires only the geometrical properties to be known, whereas a detailed assessment usually requires additional physical model parameters. This deterministic method is also called *semi-probabilistic,* because prescribed partial safety factors implicitly ensure that the annual failure probability stays always below an allowed value per section and mechanism.

The new VTV-2017 regulations will also support this VTV-2011 type deterministic assessment per mechanism and section. Part of the TOI project will therefore aim at the calibration of the safety factors for the final VTV-2017 mechanism models in 2017. Additionally, the new VTV-2017 regulations and supporting software will allow an explicit *probabilistic* assessment, taking into account the combined contributions from different failure modes and different sections. The prescribed failure mechanism models for detailed probabilistic and semi-probabilistic analysis will be identical. The VTV-2017 will also prescribe how to combine the results from sections and mechanisms that were assessed with different methods.

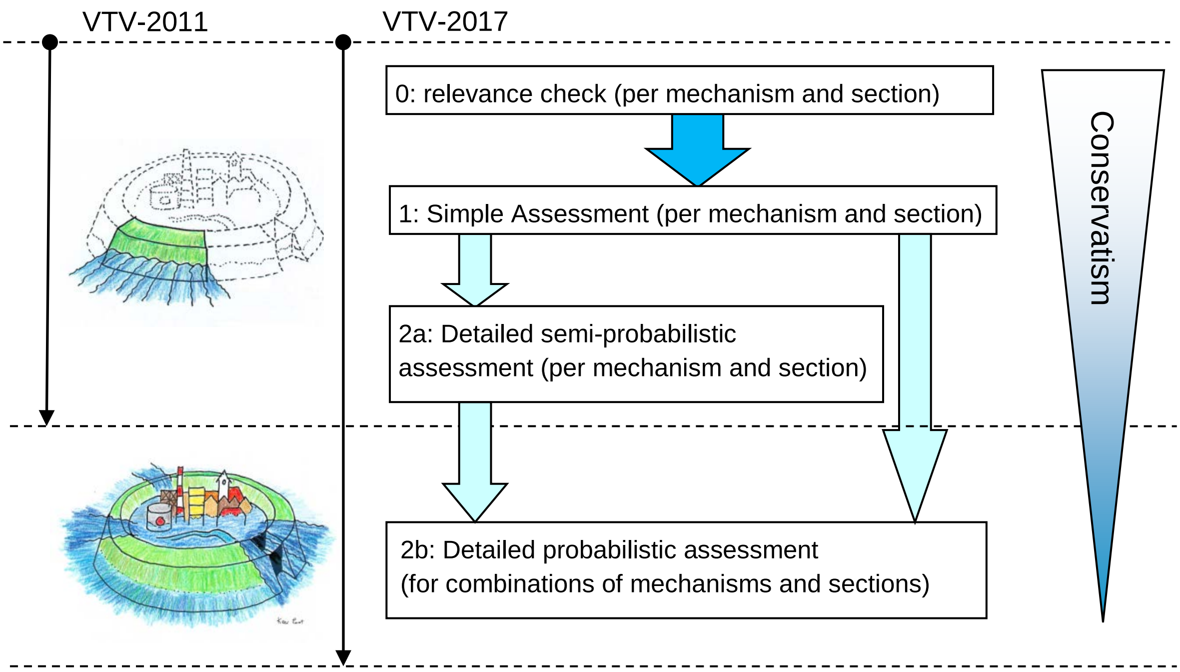

Figure 1.4 VTV-2017 assessment scheme, with additional new level 2b. Level 3 (advanced) is not shown. Also not shown is the additional assessment, based on criteria defined by the regional water authority (beheerdersoordeel)

The result of a semi-probabilistic assessment is usually a certain factor of safety (FOS) per mechanism and section. A FOS is determined by the ratio between the allowed and actual value of certain load type (e.g. an overtopping discharge, a differential head for piping or a driving moment for slope instability). The result of a probabilistic analysis is an integrated failure probability for (a part of) a dike ring, which has to be compared with the allowed value. The failure probability is influenced by the uncertainty in both hydraulic loading and strength, as well as by the length and number of the sections. A probabilistic analysis for combined mechanisms and sections is always less conservative than a separate semi-probabilistic assessment per mechanism and section.

1.4.3 Global Assessment Work flow

Figure 1.5 depicts the global assessment work flow which is to be supported by Ringtoets.

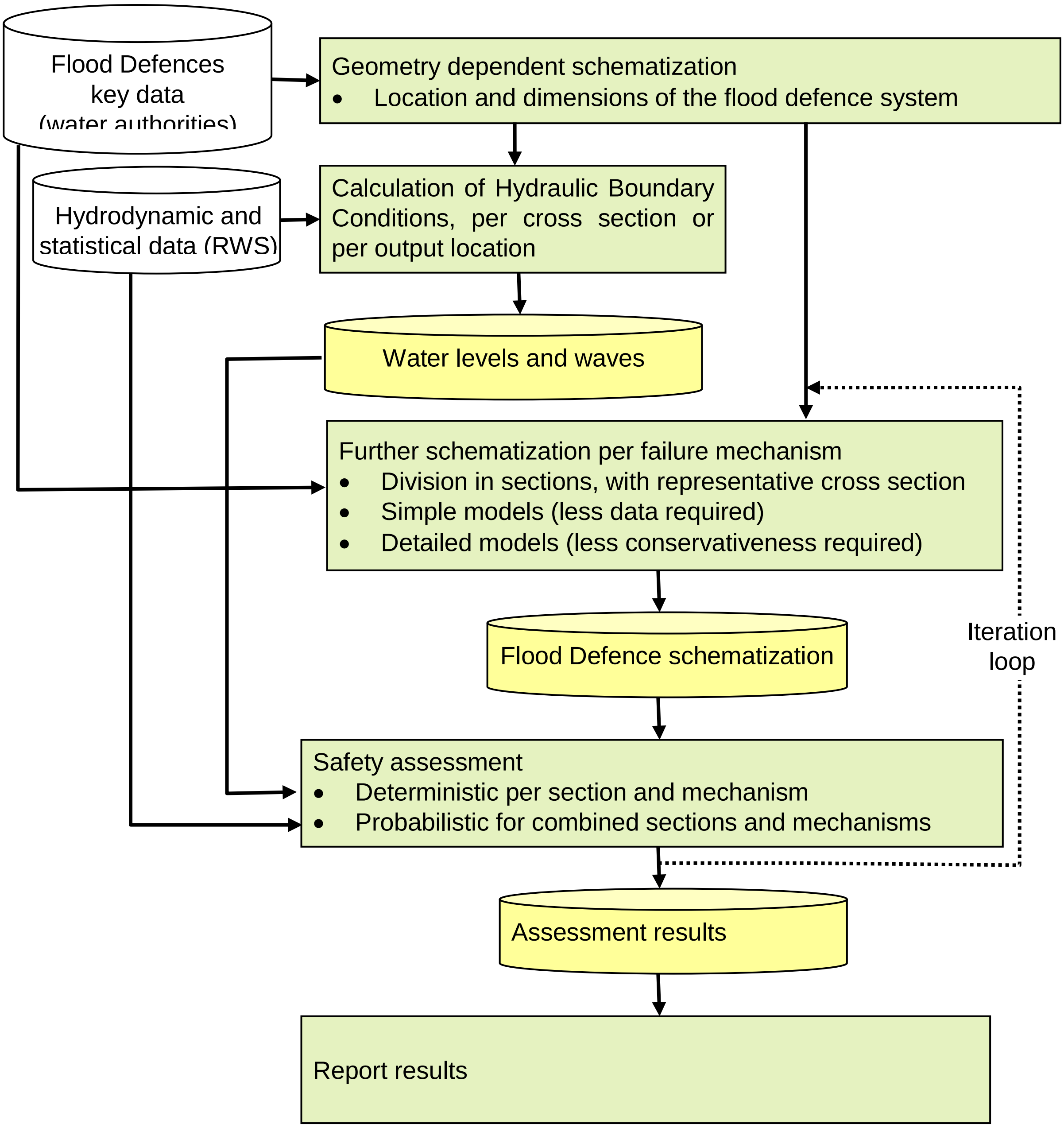

Figure 1.5 Work Flow Safety Assessment. Ringtoets covers all tasks which are coloured green. The additional containers show the initial data (white) and project data (yellow). The Water authorities are responsible for delivering the flood defences key data and for executing the schematization and assessment. Rijkswaterstaat (RWS) is responsible for delivering the hydrodynamic and statistical data, and delegates the production to Deltares. The hydrodynamic data is contained in different physical databases for different regions. The project database content (flood defence schematizations, hydraulic boundary conditions, and assessment results) is coloured yellow.

Section 2.3 contains a more detailed description.

1.4.4 Stakeholders and users

- Rijkswaterstaat is responsible for delivering the assessment tools, including the format and content of the hydrodynamic database, as well as for the data format of the schematization and assessment results and the format of the final assessment report.
- The regional water authorities (waterschappen) and Rijkswaterstaat are the end-users, responsible for the execution of the actual assessment, including data acquisition, schematization, analysis and reporting.
- The regional water authorities commission their assessment tasks mostly to specialized civil engineering consultants. The total number of consulting employees doing actual assessments is not more than two hundred.

During the Ringtoets definition and development stage, Deltares will frequently consult the Ringtoets Advisory Group in order to get feedback on intermediate results. This group consists of both the regional water authorities responsible for assessment and the consultants to which assessment tasks are usually delegated.

Related to the WTI as a whole, the “Directoraat-Generaal Waterstaat” is primary responsible for all formal communication with public administration representatives and the Waterdienst is primary responsible for all formal communication with the regional water authorities (in coordination with the “Directoraat-Generaal Waterstaat”). Deltares is finally responsible for communication with the civil engineering consultants (in coordination with the Waterdienst).

1.5 System documents

Together with the document in hand, the following documents comprise the currently available system documentation for Ringtoets and Hydra-Ring. All these documents are under continuous development, until the VTV-2017 regulations and associated software will be formally released in 2017.

Document	*Content*
Project Start Architektuur TOI [Lit 6.7]	Gives constraints for usage of TOI within the infrastructure of Rijkwaterstaat and the water boards.
Het raamwerk en de aanpak van het toetsproces: voorstel [Lit 6.6]	Proposes a structure and approach for the new safety assessment procedures (VTV-2017), which are to be supported by Ringtoets.
Hydra-Ring Design document [Lit 6.2]	Describes the requirements for Hydra-Ring, as well as the design of the software structures, the data structures and the databases (project database, general configuration database, statistical configuration database, hydrodynamic databases per region).
Hydra-Ring Scientific documentation [Lit 6.1]	Describes the methods and algorithms used in Hydra-Ring. Serves as the basis for the scientific background in the final User’s manual of Ringtoets.

1.6 Assumptions and Constraints

Ringtoets has to comply with the following assumptions and constraints (CNS), related to the different purposes of Ringtoets at the different stages of the development. The reason for defining these assumptions and constraints prior to the definition of the requirements in chapter 3, is that each of them will affect multiple requirements. Assumptions are also needed to specify the still undefined or uncertain parts of the WTI project context to a sufficient detail.

CNS 1 The draft document “Project Start Architektuur TOI” [Lit 6.7] defines the constraints provided by Rijkswaterstaat[1].

CNS 2 The Deltares report “Uitgangspunten WTI” [Lit 6.12] defines the general assumptions and constraints for the Deltares WTI project as a whole.

CNS 3 The first evaluation version of Ringtoets must be available at the start of the evaluation period, which is tentatively in the course of 2013. The aim of the evaluation version of Ringtoets, in combination with the evaluation version of Hydra-Ring, is to support semi-probabilistic and probabilistic analysis of all Dutch primary flood defences, with a functionality similar to the Hydra’s and to PC-Ring.

CNS 4 Ringtoets will support the deterministic and/or probabilistic analysis of all mechanisms contained in a new VTV-2017 software library of failure mechanisms. The specifications of different VTV-2017 failure mechanism models however, as well as the subsequent specification and development of the software library itself are not a part of the Ringtoets specification and development.

CNS 5 The requirements and limitations for probabilistic analysis with Ringtoets (level 2b) are already defined in the Hydra-Ring design document [Lit 6.2]. This includes the requirements on the failure mechanism models and hydraulic load models to be supported probabilistically for respectively the evaluation version and the product version. This includes also the requirements and limitations with regard to the use of mechanism sections. And it finally includes the specification of the Hydra-Ring interface.

CNS 6 Besides level 2b, Ringtoets needs to support also the decision rules in level 1 and a semi-probabilistic assessment in level 2a, as well as the combination of probabilistically assessed parts with semi-probabilistically assessed parts. Ringtoets is not expected to support decisions with regard to the relevance check (level 0). Ringtoets is also not expected to support a level 3 assessment (*Toetsen op maat*) and additional assessment procedures, such as *Beheerdersoordeel*.

CNS 7 The first product version of Ringtoets is planned in 2016, before the start of the next assessment period in 2017. The aim of this product version is to supply full support for assessment with prescribed VTV-2017 models and procedures for at least 9 failure mechanisms (including simple or detailed deterministic assessment), with the help of Hydra-Ring.

1. *The general constraints for Rijkwaterstaat software (such as huisstijl and web-based design) are not applicable for RIngtoets.*

CNS 8 The applicability of Ringtoets will be limited to safety assessment for all Dutch primary flood defences (category a, b and d), based on the VTV-2017.

CNS 9 According to Rijkswaterstaat, the final reporting of assessment results by the regional water authorities, in a fixed digital format, is not a part of the required Ringtoets functionality. Instead, a connection to an external reporting module such as *Toetsrap* is envisaged. The specification of such a module is therefore not a part of the current Ringtoets definition[2].

CNS 10 The first product version of Ringtoets is not expected to offer automated design capabilities (i.e. functionality for automated determination of the required geometrical and physical properties, similar to the DAM software). The Ringtoets design must however allow for such an extension in the future.

CNS 11 Ringtoets will supply some basic data visualization and data elaboration options as found in GIS systems and spreadsheets, and use data-connections to existing external GIS systems and/or spreadsheet software for further functionality. This means that Ringtoets will not fully replace the functionality of already existing GIS and spreadsheet software. This philosophy is shared with the Hydra's and with the DAM software. Further details on the supported options will be supplied as part of the definition of the requirements (chapter 3) and the use-cases (chapter 4).

CNS 12 Possible access to a remote Ringtoets installation via a Citrix web client is a minimum requirement for Rijkswaterstaat. It is however not a Rijkswaterstaat requirement or user requirement that the user-interface is fully web-based (meaning: access via a web browser, without Citrix client software).

CNS 13 Ringtoets must be capable to import a snapshot of all key data from the original data sources maintained by the regional water authorities, using the same exchange formats and methods as DAM (Dike strength Analysis Module) already does. The reason for this constraint is that that the water authorities obviously want to maintain only one single data source for both DAM and Ringtoets.

CNS 14 The models and algorithms supported by Ringtoets are not expected to be exactly equal to the models and algorithms supported by PC-Ring and the Hydra's. Therefore, the numerical results are also not expected to be exactly equal. However, the trends and ratio of results are expected to be comparable.

CNS 15 Ringtoets will not offer capabilities for direct import of PC-Ring or Hydra input, as the input data model of Ringtoets will be different. Instead it is assumed here that re-use of existing PC-Ring data (from the VNK project) during the test and evaluation period will be achieved via preprocessing. Automation of this preprocessing will however be not a part of the Ringtoets development.

CNS 16 Rijkswaterstaat allows the use of third party software as part of Ringtoets, as long as this software does not require a separate user licence fee, and as long the

2. *The structure of the workflow supported by Ringtoets will be different from the formal VTV-2017 structure to report the final assessment results.*

availability is guaranteed for a minimum period of 10 years. This constraint does not apply to existing external software that has to be used in conjunction with Ringtoets.

1.7 Summary of relevant concepts and procedures

Some important concepts and terms for understanding the functional requirements are explained globally hereafter. A full glossary of terms is presented in appendix A and B. For more detail on the mentioned concepts, models and procedures, the reader is referred to the scientific documentation [Lit 6.1].

1.7.1 Failure mechanisms

A flood defence system consists of sections of dikes and/or dunes, with interjacent structures. A flood defence system can fail (meaning: lose its water retaining function) due to different *failure mechanisms*. An overview of relevant mechanisms for dikes is shown in Figure 1.6.

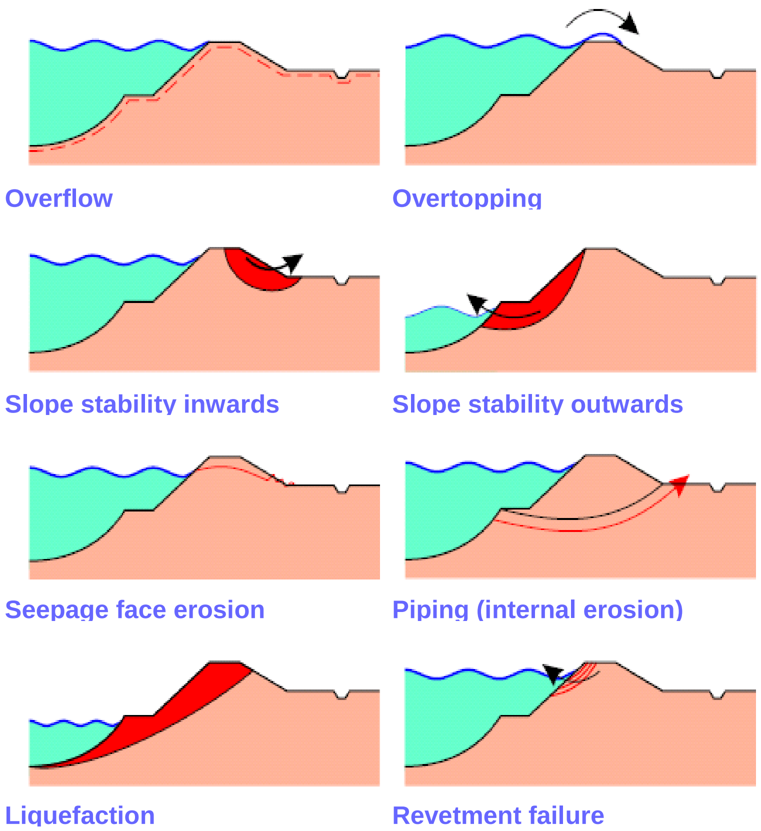

Figure 1.6 Illustration of different failure mechanisms for dikes.

Sometimes, actual failure will depend on the occurrence of more than one *submechanism*. An example is failure due to piping (internal erosion of sand underneath the dike or structure), which can only occur after preceding uplift of the protecting cover layer at the land side, see Figure 1.7. Another example is the failure of the inner slope due to erosion or instability, after a preceding occurrence of overtopping.

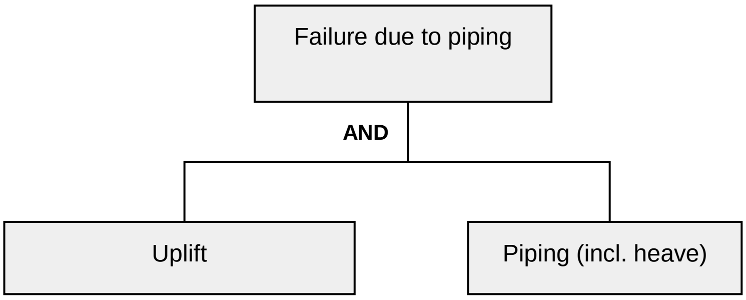

Figure 1.7 Example of the fault tree for failure mechanism piping

Submechanism failure is predicted on the lowest level by *cross sectional models*, requiring input that is partially model specific. A cross section can contain different zones of revetment, which need to be assessed per zone.

1.7.2 Assessment levels and section divisions

The safety assessment for different failure mechanisms according to the VTV-2017 must be executed stepwise on different levels, according to Figure 1.4 and Table 1.1.

Table 1.1: Overview of assessment levels

Level	Type of assessment	Outcome
0	Relevance check per cross section and mechanism	When the failure mechanism is not relevant for a cross section, the annual failure probability (FP) is assumed to be zero.
1	Simple semi-probabilistic assessment per cross section and mechanism	When the result of the simple assessment is positive, the annual FP is below a certain allowed value as derived from the 'failure probability budget'
2a	Detailed semi-probabilistic assessment per section and mechanism	The ratio between the conservatively determined deterministic strength and load is usually expressed via a factor of safety (FOS). The use of partial safety factors ensures that, when the FOS is larger than 1, the failure probability is below a certain allowed value as derived from the 'failure probability budget'.
2b	Detailed probabilistic assessment (for combinations of sections and mechanisms)	The result of the detailed probabilistic assessment will be the annual FP for the each failure mechanism per section, as well as an overall failure probability for the combined failure mechanisms and sections.

As part of a level 2 assessment, the total stretches of dunes and dikes are divided by the user into different longitudinal *mechanism sections*. Inside each of these sections, the different input parameters for the considered mechanism model(s) are assumed to be more or less constant, but uncertain. The length of a section should be sufficient large for a failure mechanism to occur.

In case of a semi-probabilistic assessment (level 2a), the assessment results from different mechanism sections (OK or not OK) are combined on so-called *combination sections*. The joined boundaries of all different mechanism sections determine implicitly the division into combination sections. The purpose of combination sections is to decide for which parts a semi-probabilistic assessment is sufficient, when considering all mechanisms together.

In case of a probabilistic assessment (level 2b), the user will be able to define additional *presentation sections*. A presentation section consists of one or more combination sections. A presentation section is used for combination of the failure probability contributions from different mechanism sections, in order to determine if physical improvement of the section is required.

See section 2.3 for further details on the stepwise assessment and section divisions.

2 Scope

2.1 System definition

The main goal of Ringtoets is to support the required model schematizations by the user and afterwards execute an automated assessment of primary Dutch flood defences, according to the VTV-2017 regulations. Schematization means the process of producing model input for a subsequent assessment, starting from already available key data. Automated means that Ringtoets will execute the assessment for combinations of multiple mechanisms and sections. It is intended that Ringtoets will finally replace PC-Ring and the Hydra's, which together offer similar functionality.

Ringtoets will have four main functionalities:

1. Support for schematization using imported or inputted data, for the purpose of assessment;
2. Calculation of the hydraulic boundary conditions;
3. Execution of safety assessments on different levels (simple, semi-probabilistic and full probabilistic calculations) and combination of the assessment results;
4. Presentation of assessment results.

Figure 2.1 shows the global Ringtoets design. The main functions are steered by a controller, connecting to a graphical User-Interface (UI), an input/output (IO) layer and a business layer.

- The user interface enables tabular or graphical presentation and manipulation of the project-data, the model schematization and the calculation results.

- The input/output layer connects to the internal project database, and to different types of external databases and files. The external data sources are shown at the left hand side[3]. A GIS and a subsoil database (D-Soilmodel) are expected to be used increasingly by the waterboards as the original source for processed key data. Data exchange with Ringtoets is expected to be performed through CSV or SHP files. The CSV format allows also for connection to external spreadsheet software. The additional XML format is expected to be used mostly for archiving and exchanging project data, as well as for connection to external software, such as a formal VTV-2017 report module. Map data is expected to be imported through shp files.

- The business layer performs the tasks for assessment on all relevant levels and contains also the definition of the shared data-model. The business layer connects to the Hydra-Ring component for the probabilistic assessment (level 2b).

Ringtoets connects to software libraries containing components that are shared with other tools, including the stand-alone VTV tools and DAM (Dijksterkte Analyse Module). Sharing libraries between these tools will enable uniform connections to single data sources, a uniform look and feel and equivalent results from the shared mechanism models. Using shared libraries will also reduce the maintenance effort for each of these tools.

3. *Import and export to NetCDF is currently not foreseen as a user requirement.*

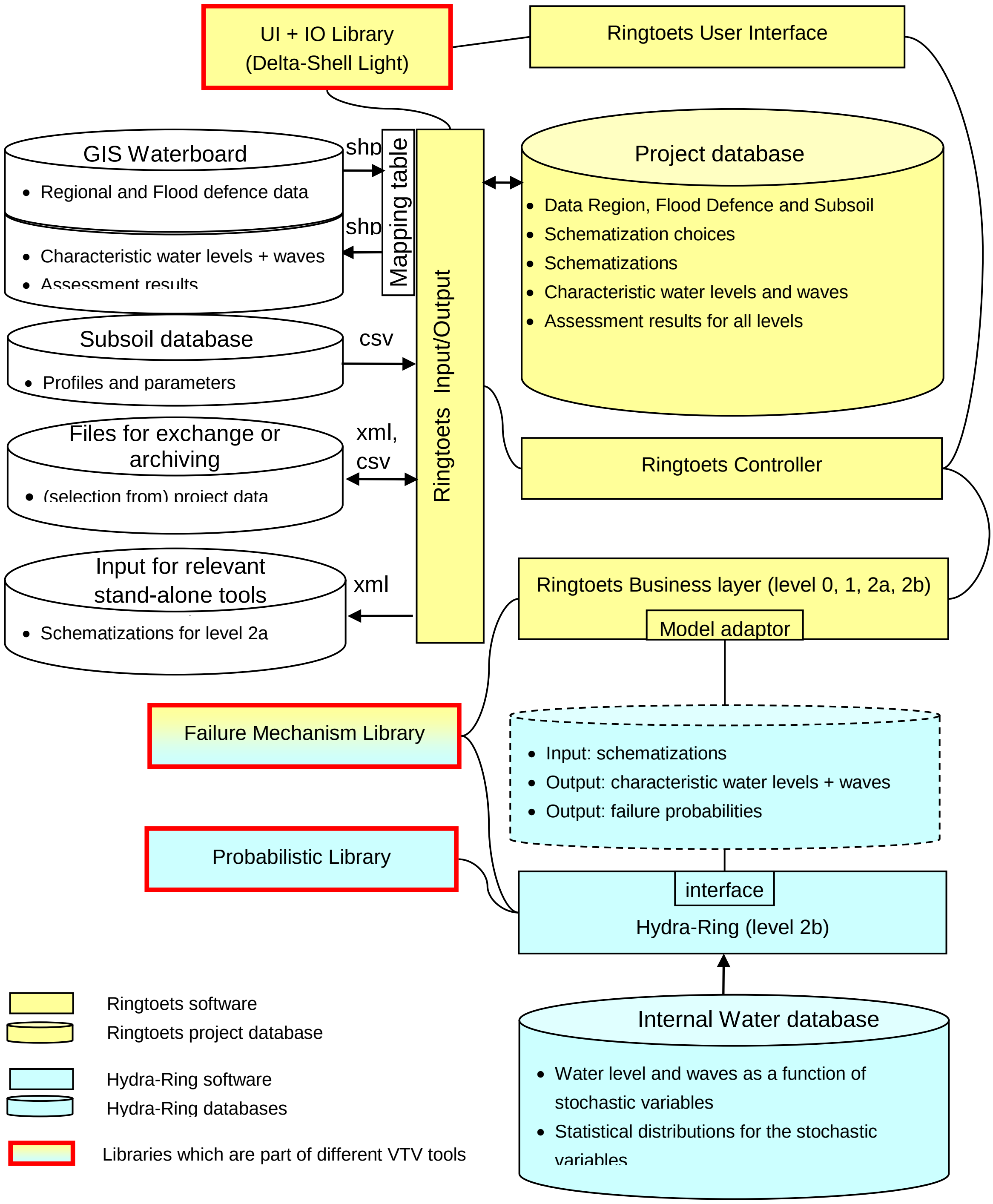

Figure 2.1 Global design of Ringtoets

2.2 Main features

Schematization using imported or inputted data
Ringtoets will have functionality for input or import of data, and support the schematization process from processed data to the required model input for assessment, either semi-probabilistic or probabilistic. The user can specify the geometrical and physical properties of flood defence sections per mechanism. The user can connect these sections to predefined locations of hydrodynamic data, already available in databases. The graphical user interface will support the schematization process by offering tools for visualising, editing and modifying the properties per mechanism and longitudinal section.

Calculation of hydraulic boundary conditions
Ringtoets will offer a probabilistic calculation of the water levels, waves and overtopping characteristics at different locations. Ringtoets will use the output at cross section locations for a subsequent semi-probabilistic assessment of different failure modes.

Execution and combination of safety assessment on different levels
The main functionality of Ringtoets is to execute safety assessments on different levels. This means that a user can perform simple geometry based assessment, detailed semi-probabilistic assessment and detailed probabilistic assessments with the help of Ringtoets. Ringtoets will also support the combination of assessment results from different mechanisms and different sections, potentially assessed at different levels.

Presentation of assessment results
Ringtoets can present the primary calculation results in tabular format. Additionally, some basic support will be supplied for graphs in time or space, and for visualization of results on map/GIS layers. Output of detailed semi-probabilistic results per mechanism and section is very important for a user, in order to gain confidence in the quality of the output. The contribution to the total probability of each individual failure mechanism at a certain section is of great use for the engineers. Post-processing will also be supported by output of data to xml or csv files (section 3.3.8).

2.3 Supported tasks and workflow

2.3.1 Overview

A schematic overview of the tasks to be supported at different levels for a regular assessment procedure is given in Figure 2.2. This scheme enables a part of the required assement according to the VTV-2017, as far as currently known [Lit 6.6]. It should be noted in advance that Ringtoets will not support “Toetsen op maat” and “beheerdersoordeel”, see CNS 5.

The presented scheme indicates that the initial relevance checks (level 0), calculation of hydraulic boundary conditions and further geometry based assessments (level 1) could be executed in principal at all considered cross sections. The result of such a cross section analysis reveals which stretches per mechanism require a more detailed level 2 assessment.

A level 2a or 2b assessment is executed at the level of longitudinal sections (“dike sections”), containing one or more cross sections. The definition of the section division per mechanism within the relevant stretches should be performed with the help of: (a) the result from the preceding cross section analysis and (b) an analysis of the spatial variability of the boundary conditions and the additionally required model data per mechanism.

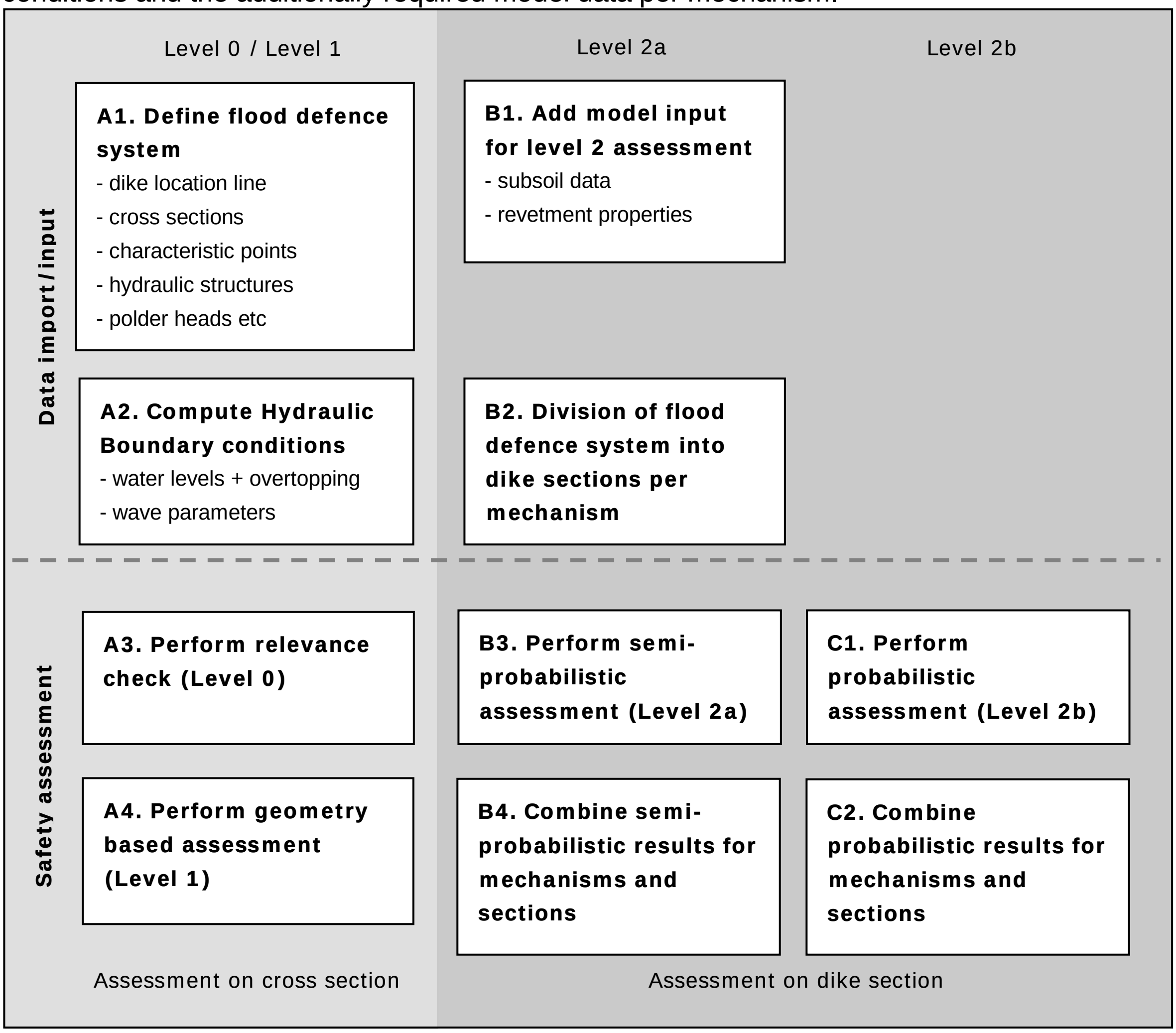

Figure 2.2 Schematic tasks for safety assessment, as far as supported by Ringtoets.

2.3.2 Detailed Workflow

Details on the workflow that needs to be supported are presented below, in bullet style. The purpose of this description is mainly to help in deriving and understanding the related requirements. The workflow description will be restricted to three typical mechanisms (overflow/wave overtopping, revetment, heave/piping). Extension of the description to additional mechanisms is however quite straightforward.

A. Definition of cross section geometry and determination of the required assessment level per cross section, with the help of relevance checks (level 0) and geometry based checks (level 1).

Determine the required assessment level per mechanism and per cross section

- Characteristic values of hydraulic boundary conditions per cross section
- Check if mechanism is irrelevant (level 0), if level 1 is sufficient, or if level 2 is required

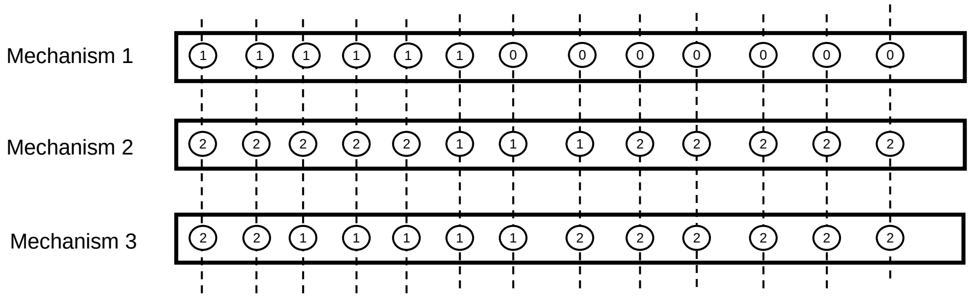

Figure 2.3 – Determination of required assessment level per mechanism and cross section.

A1. Define Flood defence system

- Input or import the actual dike location line of the flood defence system[4]
- Input or import processed cross section surface lines (from Digital Terrain Model in GIS).
- Optional: import existing definitions of characteristic point verticals along the dike line (such as outer levee toe, outer levee crest, inner levee crest, inner levee toe, berm crest, berm toe etc.)
- Define or update the locations of the characteristic points
- Import or define the inland piezometric head (polder head) distribution along the dike location line
- For revetments and wave overtopping/overflow: import or input the location and properties of different revetment zones
- For revetments and wave overtopping/overflow: import or input the locations and properties of breakwaters and foreland, both causing wave reduction.

See UC 10 (page 40) to UC 17 (page 42) for details on the required key data. Note that the full key data includes already processed data, such as surface descriptions, subsoil schematizations and model parameters.

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4. *Two different versions of the dike line can exist (the global location according to the Rijkswaterstaat administration, and the actual location according to the water authority)*

A2. Compute water level, overtopping level and wave data

- Use Hydra-Ring to calculate the characteristic assessment water level (the water level with a certain annual exceeding probability) along the flood defence system, at the toe of each location where measured cross section geometry is available, or at each output location. See UC 25 (page 45) for details.
- If wave parameters are not available directly from the internal database with hydrodynamic data: import or input fetch lengths per wind direction.
- Use Hydra-Ring to calculate the wave data for a revetment assessment[5]. See 0 details.
- Use Hydra-Ring to compute overtopping probabilities as a function of crest height, using a schematized surface. See UC 27 for details.

A3. Perform level 0 assessment

- Select the mechanisms that can be excluded in advance along which part of the flood defence system, based on a relevance check[6].

A4. Perform level 1 assessment [7]

- For heave/piping and slope stability checks: input or import the piezometric heads at polder side
- For all mechanisms: apply geometry based (level 1) decision rules along the defence system when applicable and decide which parts of the flood system can be excluded for further assessment
- View results per mechanism: cross sections along the dike location line requiring level 1 or level 2 assessment. The associated output is illustrated in Figure 2.3.
- Optional: export previously inputted or modified data.

See from UC 28 (page 48) to UC 31 for details on step A4.

5. *Wave parameters for revetment at different heights need to be determined in the so-called "design point" (illustratie punt), with a special approximated limit state function, such as:* $R - H_s{}^a T_p{}^b$ *, where R is some user-defined measure of strength.*
6. *According to CNS 6, Ringtoets will not support the decision rules for a relevance check*
7. *According to [Lit 6.12], it is assumed that a cross section passing the level 1 assement does not consume any failure probability budget.*

B. Semi-probabilistic assessment

Create sections and perform semi-probabilistic check (level 2a)
- Characteristic values of hydraulic boundary conditions per level 2 section
- FOS (factor of safety) value per level 2 section, per sub mechanism and per layer
- Check if FOS is sufficiently large per level 2 section, per sub mechanism and per layer. If not: a probabilistic analysis is required (level 2b)

Semi-probabilistic output for combination sections
- Check where FOS is sufficiently large for all combined mechanisms

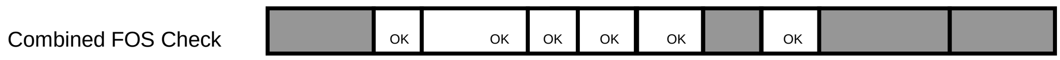

Figure 2.4 – Semi-probabilistic assessment per mechanism section

B1. Add model input for level 2 assessment, for selected stretches
- For revetments:
  - Import of input for each revetment zone the physical properties to be used inside mechanism models: (a) mean value, (b) statistical standard deviation, (c) standard deviation.
- For heave/piping:
  - import or input a material library with different soil types and physical properties, if available. This library contains for each property: mean value, statistical standard deviation, standard deviation for mechanism model(s).
  - import or input a set of possible 1D soil profiles (a stack of different soil layers) including a link for each layer to the soil library.
  - For one or more characteristic lines along the flood defence (river axis, outer toe, levee axis, inner toe, ditch axis, polder side): attach one or more probable soil profiles to certain stretches along the line and define the probability of occurrence along the stretch. Or use imported soil profile distributions along the characteristic lines.
- Optionally: export previously inputted or modified data.

B2. Per mechanism: divide into sections for level 2 analysis.
- import existing section divisions from previous assessment, when available, to support the decision process.
- Overflow/wave overtopping: decide for a (modified) division into sections, based on the difference between crest height and characteristic water level.
- Revetment: decide for a (modified) division into sections, based on the location and types of revetment layers.
- Heave/Piping: decide for a (modified) division into sections, based on the variation in subsoil conditions, in geometrical properties and in hydraulic loading.

- Optionally: export previously inputted or modified section divisions.

B3. Optional: Perform semi-probabilistic analysis (level 2a)
- Revetment
  - Define the partial safety factors to be used for physical properties and hydraulic loading
  - Per section:
    - Define the characteristic cross section surface.
    - Compute the characteristic wave parameters and characteristic load durations at different heights along the flood defence system with Hydra-Ring.
    - Determine the partial factor for the influence of section length
    - Per revetment layer along the outer slope:
      Compute characteristic values of physical properties, using mean values and standard deviations from the material library.
    - Compute the factor of safety for failure by wave attack (damage and subsequent erosion), depending on the revetment type, using the prescribed mechanism models.
    - View relevant output details.
- Uplift/Heave/Piping:
  - Define the partial safety factors to be used for physical properties and hydraulic loading
  - Per section
    - Determine the partial factor for the influence of section length.
    - Define the characteristic cross section surface.
    - Select the characteristic subsoil profiles in the cross section direction from the set of probable profiles and determine the associated schematization factor. This results in a 1D or 2D schematization in cross section direction.
    - Import or define the schematized hydraulic head distribution in the characteristic cross section aquifers as a function of the external water level, by an entrance point and a damping factor at the inner toe for each aquifer.
    - Compute characteristic values of physical properties for the mechanism models, using mean values and standard deviations from the material library.
    - Check if heave will occur at some location along the polder side.
    - In case of heave: compute the critical differential head, the minimum piping length and the Factor of Safety, using the prescribed mechanism models.
    - View relevant output details.
- Overflow/overtopping
  - Define the partial safety factors to be used
  - Per section:
    - Select the characteristic cross section surface (already schematized in step A2).
    - Compute and view relevant output details on that cross section.

B4. Optional: Combine semi-probabilistic results from different mechanisms and sections.
- Check at which stretches the result from semi-probabilistic analysis for any of the mechanisms is insufficient. Stop if semi-probabilistic checks along the total flood defence are sufficient for all mechanisms.
- Optionally: export the semi-probabilistic schematization and results.

See from UC 32 (page 50) to UC 36 for details on step B.

C. Partially probabilistic assessment (Level 2b + level 1)

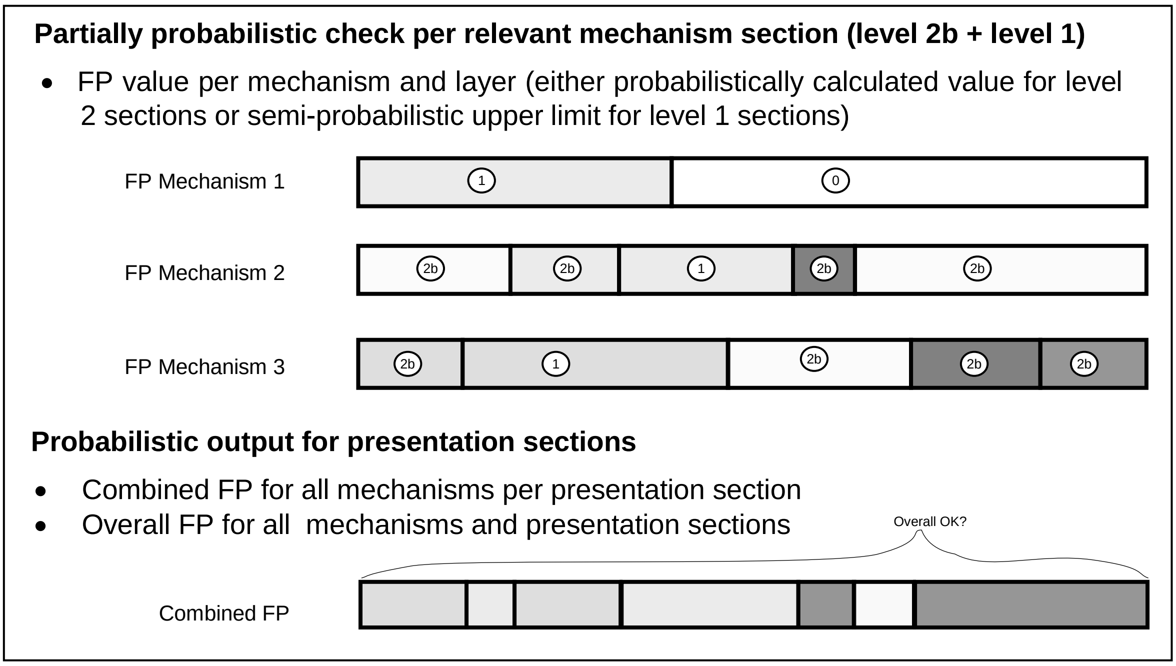

Figure 2.5 – Partially probabilistic assessment of the combination of mechanism sections

C1. Perform probabilistic analysis, using the same section division and model input as for semi-probabilistic analysis

- If required: modify default settings for probabilistic procedures.
- Overflow/wave overtopping:
  - (Define the model uncertainties to be used and the allowed factor of safety).
  - Per section:
    - Re-use the characteristic cross section defined for level 2a assessment.
    - Define the characteristic allowable overtopping discharge, or select the model to compute the allowable discharge as part of the probabilistic procedure.
    - Compute the annual failure probability per section with Hydra-Ring.
- Revetment
  - (Define the model uncertainties to be used and the allowed factor of safety).
  - Per section:
    - Re-use the characteristic cross section defined for level 2a assessment.
    - Compute the annual failure probability per section by wave attack (damage and subsequent erosion), depending on the revetment type.
- Uplift/Heave/Piping:
  - (Define the model uncertainties to be used and the allowed factor of safety).
  - Per section
    - Define the characteristic cross section surface, or use a stochastically defined cross section geometry.
    - Either use a characteristic 1D or 2D subsoil profile in cross section direction with associated schematization factor, or use a set of probable profiles (scenarios) with a probability of occurrence for each possibility.
    - Define the schematized hydraulic head distribution in the characteristic cross section aquifers as a function of the external water level, by input of an entrance point and a damping factor at the inner toe for each aquifer.

- Determine the partial factors, including the influence of section length.
- Compute the failure probability with Hydra-Ring, using the prescribed mechanism models.

C2. Combine failure probability contributions from mechanisms and sections

- Calculate the allowed failure probability of the combination of probabilistically assessed parts, after subtracting the failure probability budget for semi-probabilistically assessed parts.
- Import or define a division in presentation sections for the probabilistically assessed parts for combination of mechanism contributions.
- Calculate the failure probability per presentation section and for all probabilistically assessed parts and view the resulting FP values for the different sections.
- If the total FP is too large: decide if the model schematization should be refined with the help of additional data.
- If the total FP is still too large: Give an indication of the presentation sections that need to be improved based on probabilistic assessment (the sections with the largest contributions).
- Optionally: export the probabilistic schematization and results.

See from UC 38 (page 53) to UC 44 for details on step C.

Final remarks concerning section divisions and output per assessment water level:

1. In case of a semi-probabilistic level 2a analysis, the FOS is the basic output per (sub)mechanism, per layer and per section.
2. In case of a semi-probabilistic analysis, a FOS check (OK or not OK) is the basic output for combined mechanisms and sections.
3. In case of a semi-probabilistic analysis, the FP budget values per mechanism and section are also required as output, for combination with probabilistically assessed parts.
4. In case of probabilistic analysis, the model input is assumed to be equal as for detailed semi-probabilistic analysis.
5. In case of probabilistic analysis, Hydra-Ring will be capable to calculate the combined FP on presentation sections, taking into account the contributions from parts of different mechanism sections.
6. For the purpose of combining probabilistic and semi-probabilistic parts, the possible locations of presentation section ‘cuts’ should be limited to the locations of mechanism section cuts. Or in other words: a presentation section consists of one or more combination sections.

3 Requirements

3.1 Introduction

The following sections present an overview of the general, functional and non-functional requirements. The functional requirements also include some rules and constraints for the design of the graphical user interface. One of the following importance indicators is attached to each of these requirements.

- Must have: minimally required for basic usage.
- Should have: additionally required for practical usage.
- Nice to have: additionally desired to support practical usage.

3.2 General requirements

General requirements focus on the main functionalities of Ringtoets. The general requirements are system qualities that the Ringtoets program must have, to support the assessment methodology of dikes. Ringtoets should meet for this purpose the following general functional requirements (GR).

GR 1 Ringtoets must comply with general requirements and preferences for the TOI project, as much as practically possible. These preferences are derived from [Lit 6.5]. (must have)

GR 2 The first product version in 2016 needs to support a probabilistic and semi-probabilistic assessment for multiple mechanisms and sections. The probabilistic analysis tasks will be executed by Hydra-Ring must have).

GR 3 The features of Hydra-Ring and supporting tools must include the output features of the existing Hydra software and supporting tools, as well as all calculation and output features of the existing PC-Ring software, as far as required for an assessment according to the VTV-2017[8]. (must have)

GR 4 The first product version in 2016 must support all final mechanism models, hydraulic load models and assessment procedures as prescribed by the VTV-2017 and the defining documents to which the VTV-2017 refers, as far as these models are part of the VTV-2017 software library for failure mechanisms. See Table 3.1 for a tentative list. (must have)

GR 5 The initial evaluation version of Ringtoets (at the start of the evaluation period) must already offer capabilities for probabilistic production of hydraulic boundary conditions (water level and wave parameters), as well as a probabilistic assessment for a selected number of mechanisms (Table 3.1), in combination with the TMR2006 hydraulic data set. (must have)

GR 6 Multiple users should be able to work simultaneously (collect data, schematize and calculate) on different mechanisms, and/or on different parts of one dike ring area.

8. *It is not required that the supported models and algorithms are equal to PC-Ring and the Hydra's, see CNS 14*

This requires ideally a locking mechanism, to restrict the input access for selected mechanisms and sections to a certain user. (should have)

GR 7 The user must be able to supply model input either by importing data or by adding data via the graphical user interface (GUI). (must have)

GR 8 Semi-automated schematization from processed key project data to model data will be supported where possible. (should have)

GR 9 Ringtoets will supply clear and sufficient feedback to the user (e.g. progress, error and warning). (must have)

GR 10 Ringtoets will support tabular and (limited) graphical output presentation options. (must have)

GR 11 The User Interface, the feedback messages and the reports will have a Dutch and English language mode. (must have)

GR 12 The full theoretical background of Hydra-Ring will be available in English language. (must have)

GR 13 The User Manuals will be in available in Dutch language, and contain a reference part, a tutorial part and a summary of the theoretical background. In the theoretical part, references will be made to the full theoretical documentation of Hydra-Ring (in English language). (must have)

Table 3.1: Expected support of mechanism models in Ringtoets in 2017 (depending on results from other WTI and SBW subprojects)

Type of flood defence	**Evaluation version**	**Product version**
Dike sections	- Overflow / wave overtopping - Heave/Piping - Instability of the inner slope - Failure of the revetment	- Overflow / wave overtopping - Piping - Instability of the inner slope - Failure of the revetment - Instability of the outer slope - Micro instability*
Dunes		- Dune erosion - Wind erosion*
Hydraulic Structures	- Overflow / wave overtopping - Piping	- Overflow / wave overtopping - Piping - Structural failure* - Non closure of gates or doors*
General		- Strength and stability of transitional structures* - Foreland instability* - Failure due to non water-retaining structures* - Failure of vertical walls and other structural elements in dike sections (i.e. sheet pile walls)*

* provided the timely availability of suitable software models in the VTV-2017 failure mechanisms library

3.3 Functional requirements

The functional requirements will elaborate the relevant general requirements from section 3.2 to a more detailed level, in order to define what a user must be able to do with Ringtoets. See several use cases in chapter 4 for a more detailed specification.

3.3.1 Data connections

FR 1 Ringtoets will supply a neutral XML interface for import and export of all processed and schematized data in the project database, enabling third party development of connectors to specific formats, and also enabling connection to web services. (must have)

FR 2 Ringtoets will have an import and export connector to GIS, via shp files and a configurable mapping table (or translation table) between the GIS data and the Ringtoets data. This mapping table will relate data items in the different shp files to the Ringtoets data items (must have)

FR 3 Ringtoets will have an import connector to the same subsoil database as the one to which DAM (Dike Analysis Module) connects, via CSV files. (must have)

FR 4 For import from and export to spreadsheet tables, Ringtoets will connect to CSV files (supported by MS-Office and others). (must have)

FR 5 Ringtoets will offer options for exporting schematized data per cross section to stand-alone tools. (should have)

3.3.2 Import already available flood defence key data

FR 6 Import processed measurements, such as surface profile, piezometric polder heads etc. (must have)

FR 7 Import the locations of relevant objects, such as different revetment zones, different characteristic lines along the flood defence, breakwaters etc. (must have)

FR 8 Import existing properties of relevant flood defence objects, such as revetment properties, breakwater properties etc. (must have)

FR 9 Import an existing subsoil model (profile plus properties). (must have)

FR 10 Import selected already existing schematization choices for different mechanisms and models, such as a dike section partitioning. (must have)

FR 11 Validation of data integrity during import, e.g. check on missing data, consistency and ranges. (should have)

FR 12 All imported data must be saved to the project-database. (must have)

3.3.3 User input or modification of flood defence data

FR 13 All user input data must be saved to and retrieved from the project-database. (must have)

FR 14 A different dike section partitioning can be made for every failure mechanism. (must have)

FR 15 Input or modification of locations, dimensions, material properties, additional parameters and schematizations must be possible for all relevant mechanisms and models. (must have)

FR 16 Give suggestions for default values where possible. (must have)

FR 17 Validation of input data in user interface forms (on the fly). For example validation on syntax, completeness, limits and consistency. (should have)

FR 18 For probabilistic assessment with the help of externally defined models (advanced models and perhaps also D-GeoStability/MStab), the input of fragility curves (or actually: the linearized limit state surface for different values of the external water level) has to be supported, together with the definition of the associated stochastic model parameters (nice to have)

3.3.4 Schematization support

FR 19 Graphically supported definition of the location of mechanism sections and presentation sections. (must have)

FR 20 Start with default parameters for dike section partitioning based on generic Water Board methodology *if available* (should have).

FR 21 Selection of dike sections with ‘snap’-control. (should have)

FR 22 Graphically support the selection of one characteristic measure surface profile from a couple of measured profiles. (nice to have).

FR 23 Schematize the cross section surface profile from processed geometry data, by graphically selecting or modifying characteristic points. (must have)

FR 24 It must be possible to assign different parts of the project to different users (GR 6), based on a division by failure mechanism, and optionally also a division by sections or division by data groups as indicated in datatree. (should have)

FR 25 It must be possible to undo and redo a sequence of user actions. (must have).

FR 26 Modify relevant model schematization parameters (y-axis) in a space-graph, based on dike reference system (x-axis). (should have)

FR 27 Functionality to suggest and connect the nearest hydraulic boundary locations (hydrodynamic output locations, sometimes also referred to as “stations”) to dike sections and/or vice versa. (must have)

FR 28 Highlight the hydrodynamic output locations linked to a cross section location when selecting the cross section in top view. (should have)

3.3.5 Visualisation of input and schematization data

FR 29 Usage of GIS-layers, with the possibility to change the layer sequence and to toggle layers on/off. (must have)

FR 30 Option to change background layers (e.g. topology maps, satellite images). (must have)

FR 31 Option to use Web Map Services for background layers (should have).

FR 32 Show the location of the flood defence system with the attached points, the connected location labels (e.g. hectometrering) and the axial reference coordinate in the dike (GIS-) layers. (must have)

FR 33 Show the different section partitions per mechanism and the additional partitioning into presentation section in the dike (GIS-) layers. (must have)

FR 34 Show the schematized dike profile cross section per section and per mechanism. Put all relevant dike items in one overall dike form. Dike form items include: dike geometry, soil profile scenarios, construction elements, ditches, summer quays (winter bed), measured profile. Visual distinction between imported data and input data to actual calculation is necessary (must have).

FR 35 Show graphs of dike properties in axial direction, using the axial coordinate as x-axis. (should have)

3.3.6 Execute calculations

FR 36 Define or modify settings for different calculation methods (including the selected probabilistic method with associated parameters). (must have)

FR 37 Select output locations, cross sections, mechanism sections and presentation sections for the calculation of results. (must have)

FR 38 Define calculation options equal to the Hydra’s and PC-Ring, such as including or excluding the effect of foreland. (must have)

FR 39 Start one or more of the following calculation types:

a. Characteristic[9] water level at the output locations (river axis), as well as a table of water levels per output location for different exceeding probabilities. (must have)

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9. *a characteristic value is a value with an allowed exceeding probability*

b. Characteristic water level at the toe of selected cross sections, for a subsequent semi-probabilistic assessment, as well as a table of water levels per cross section for different exceeding probabilities. (must have)
c. Wave parameters per cross section location at different heights, for a subsequent semi-probabilistic revetment assessment. According to the Hydra software, these wave parameters need to be determined with a special approximated limit state function $R - {H_s}^a {T_p}^b$, where R is some user-defined measure of strength. (must have)
d. The required crest level per selected cross section to limit the characteristic overtopping discharge to a user-defined allowed value, as well as a table of different crest levels with different overtopping exceeding probabilities (hydraulisch belastingniveau). (must have)
e. Assessment results and FP budget per selected mechanism and section, following from semi-probabilistic analysis (level 1 or level 2a), with mechanism dependent output details. (must have)
f. FP per selected mechanism and section (incl. design point data), following from probabilistic analysis (level 2b). (must have)
g. Combination of results from semi-probabilistic and/or probabilistic analysis. (must have)
h. Fragility curves (tables of a FOS or FP as a function of stepwise variation of water level and other uncertain parameters) for different mechanisms and sections. (should have)

FR 40 Validate the complete input data (from import and additional input) before the calculation starts, resulting in a clear message of what is missing or incorrect. This type of validation is equal to the validation of imported data only (FR 11). A calculation can not start if any errors are found (must have).

FR 41 For the purpose of design, enable switching from the default assessment period (e.g. 6 or 12 years) to a longer assessment period (e.g. 50/100 year). This is achieved internally by switching to a pre-defined set of modified distributions for the stochastic variables that determine the hydraulic load. (nice to have)

FR 42 For policy studies, enable the selection of a different databases for Hydraulic boundary conditions. (nice to have)

3.3.7 Reporting and visualization of results

The following requirements reflect the input from the Advisory Group, as recorded during the first meeting. See also several use cases in chapter 4. Additional mock-ups will be prepared in an early development stage and presented to the Advisory Group, in order to refine the specifications.

FR 43 In general, Ringtoets must supply output for all the calculation types mentioned in FR 39. This comprises most of the output as given by PC-Ring, as well as all the output given by the Hydra's. (must have).

FR 44 Improve the report format compared to PC-Ring and Hydra output, give it a modern look. Use convenient defaults for configurable parameter combinations, for example cluster results per water depth vs dike system (dijkring). A good example is the 4-D table in the PC-Ring application. (should have)

FR 45 Start multiple sessions on one computer to compare different Ringtoets assessments. (should have)

FR 46 Import results from previous sessions and compare results in combined graphs. (nice to have)

FR 47 Present a report with the tabular output of different calculation types, see FR 39. (must have)

FR 48 The results report format must be such that information is grouped from general/aggregated information to detailed information. (should have)

FR 49 Add a summary table at the beginning of the report and an overview of all input parameters and settings. (should have)

FR 50 Show graphs of the different results for different divisions in axial direction, using the axial coordinate as x-axis. (should have)

FR 51 Present the semi-probabilistic assessment results graphically and tabular for different mechanism sections and combination sections. (must have)

FR 52 Present the assessment results graphically and tabular for different mechanism sections and presentation sections. (must have)

FR 53 Make the report format suitable for exporting to MS Excel. (must have)

FR 54 Make the report also suitable for exporting to HTML, PDF, XLS and other formats. (should have)

FR 55 Create a new copy of the report when specifying a new name. (must have)

FR 56 If parameters are reported with quantiles, the quantiles should be accompanied with the corresponding parameter value. (nice to have)

FR 57 Show results of individual failure mechanisms in their ‘design points’ (illustratie punten). Show contribution of single failure mechanism to the overall failure probability (including length effects). (must have)

3.3.8 Export input and results

FR 58 Export input and calculation settings via the GIS connector as much as possible, see FR 39. Hydra-Ring will not write directly into the central water board databases. (must have)

FR 59 Export the output of different calculation types via the different connectors for GIS, spreadsheets and text, see FR 39. (must have)

FR 60 Export all input, calculation settings and results via the neutral XML connector. (should have)

FR 61 Link meta-data to exported data (program version, date, data description, etc.). (must have)

3.3.9 Design rules for the Graphical User Interface

This section presents first rules and constraints that will be adopted during the actual design of the graphical user interface. These rules are based on opinions from expert users of existing assessment tools and/or GIS tools such as PC-Ring, Hydra's, D-GeoStability/MStab, PC-Vink, DAM and ARC-GIS.

FR 62 The work-process is leading in the design and hierarchy of the content in menu bars. (must have)

FR 63 The main-window contains a combination of a navigation pane, a Map window, tables/graphs and property screens. Beneath the central form there is room for a message box. (must have)

FR 64 Let the way to use GIS functionality in Ringtoets resemble the way to use it in existing GIS tools. (should have)

FR 65 Input of all data and display of all results should be possible via the menu. Additionally, data and results should be accessible via a GIS map and/or via the data navigation tree, wherever applicable. (must have)

FR 66 The active mechanism is to be selected for assessment one level higher than the active mechanism section. The selection of the active mechanism can be controlled via the menu-bar, separate navigation pane, extra form (docking) or tabs in the central form. (must have)

FR 67 The navigation pane will give access to different sections and cross sections along the dike location line, and to the (filtered) data connected to these sections and cross sections. (should have)

FR 68 The main menu will be unfoldable to a limited number of levels (two). (should have)

FR 69 Modeless forms are preferred above modal forms. Information in modeless form is actively linked to selected objects in another form (e.g. maps in project canvas). A modal form cannot lose focus within the program and has to be closed before you can continue with the program. (should have)

FR 70 Toolbars will be necessary. Critical aspects are overview and scalable graphics. (must have)

FR 71 The user must have the possibility to open, dock, hide/unhide, move and resize (sub) forms/windows. The latest window configuration must be stored and used at the next session. (must have)

FR 72 It must be possible to work with multiple screens (e.g. by spreading the several sub-windows over multiple screens). (must have)

FR 73 The usage of tabs is encouraged as a means to order large amount of parameters in forms, graphs, tables and also maps. (should have)

FR 74 Data can be partly imported from already available data sources, for example the subsoil library. When the user changes the imported data it should be made visible that the data has been changed (e.g. by showing the data in a different (background) colour). (must have)

3.4 Non-functional requirements

Non-functional requirements, also called quality requirements, describe the qualities of a program. A non-functional requirement (NFR) is a requirement that specifies the operation of a system, rather than specific behaviour or functions. Implementing the quality requirements will be detailed in the system architecture. The quality requirements are described in the following sections.

3.4.1 Standards and requirements Rijkswaterstaat

NFR 1 According to CNS 1, the Project Start Architecture document [Lit 6.7] will define to which extend Ringtoets has to comply with the following general requirements for Rijkswaterstaat software[10].

- Usage of open standards.

  http://www.open-standaarden.nl/open-standaarden/lijsten-met-open-standaarden/
- Requirements for web-interfaces.

  http: //rijkshuisstijl.communicatieplein.nl/.
- Algemene Richtlijnen Applicaties, versie 1.0
- overheidsarchitecturen NORA en MARIJ:

  http://www.e-overheid.nl/onderwerpen/e-overheid/architectuur/nora-familie/nora

  http://www.wikixl.nl/wiki/ictu/index.php/Inleiding

3.4.2 Additional conventions and standards

NFR 2 The regular conventions, standards, tools and libraries for Deltares Systems software will be used. (must have).

NFR 3 Data definitions will follow existing and emerging standards such as IRIS as much as possible. (must have)

3.4.3 Operational and accessibility requirements

10. *The applicability of these general requirements for Ringtoets is limited*

NFR 4 The installation program for Ringtoets must allow installation of an application with relevant hydrodynamic databases on individual MS Windows PC's or on Citrix servers. According to Rijkswaterstaat, the preferred installation will be on Citrix servers, offering access by multiple users inside and outside the local area network. Installation on local MS-Windows PC's needs to be possible also, for situations where a Citrix based installation is not (yet) feasible. (must have)

NFR 5 Ringtoets must allow multi-user access to the project database, which can optionally be located on an external network server. A central database on a network server can be used for direct access during assessment by users working in a Citrix environment, or for the purpose of exchanging and sharing data between users working locally on different assessment branches. (must have)

3.4.4 Logging and error handling

NFR 6 Ringtoets and its computational core must perform sufficient error checks on the validity and completeness of data during import or input, as well as during a computation. Ringtoets needs to show warnings and error messages in an error-message dialog, and write them also to a log file. The message text needs to be clear in what went wrong and where it went wrong (context). The message finally needs to supply suggestions for improvement wherever possible. (must have)

NFR 7 Ringtoets must support the selection of different logging modes for the computational core. The logging form should show the log information of the latest computation. This information can help the user when a computation does not succeed or when the user wants to analyse the quality of the calculation results. (must have)

NFR 8 Output of detailed deterministic results must enable all users to trace back the correctness of the implemented mechanism models. (should have)

NFR 9 Output of intermediate probabilistic results, in combination with documentation of the theoretical background, must enable expert users to trace back the correctness of the probabilistic procedures. (must have)

3.4.5 General Performance

No formal performance requirements have been set. During the evaluation period it will be determined if the computational performance is satisfactory under practical circumstances.

3.4.6 Capacity

NFR 10 The maximum number of simultaneous users that *view* results of a single project database is limited to 5. (should have)

NFR 11 The maximum number of users that simultaneous can *edit* one single project database is limited to 3. The users can only edit part of the project area. (should have)

3.4.7 Reliability requirements

NFR 12 The user-interface may not cause crashes during regular usage. (must have)

NFR 13 The computational core must be robust in the sense that: (a) input parameters or stochastic variation of parameters cannot upset the computations; (b) iterative procedures converge to the true solution; (c) output parameters are checked for valid ranges. (must have)

NFR 14 Consistency between the input data and the output data must be guaranteed. (must have)

3.4.8 Validation Rules

NFR 15 A documented test bench of unit tests and integration tests is required, to guarantee that numerical results are reliable and to prove that new versions give no unintended differences with previous versions. The current requirement is that at least 95% of the code of the computational core will be covered. (should have)

NFR 16 Additional evaluation and acceptance tests need to emphasize the following aspects:

a. The calculated boundary conditions should be comparable to those of the Hydra systems, if common procedures are used. (must have)
b. The results should be comparable to those of PC-Ring, for the water systems and probabilistic procedures common to both. (should have)
c. The results from deterministic mechanism models must be comparable to the results from existing VTV software for deterministic cross section analysis, as long as the schematization and boundary conditions are equal. (must have)
d. The practical applicability, robustness and performance under representative circumstances must be proven during the evaluation period. (must have)

3.4.9 Recoverability

NFR 17 Ringtoets should have an auto-save function, enabling recovery in case of unexpected disruptions during a user session. (should have)

Recovery of the project database by means of an external backup will be the full responsibility of the system administrator.

3.4.10 System availability and support

NFR 18 Version 1 of Ringtoets (software plus hydraulic databases) requires the folllowing support in the period from 2017 up to and including 2029. (must have)

The required support includes:

a. a download server with the most recent version of software, databases and documentation;
b. updates of the software, databases and documentation whenever required;
c. a helpdesk, available during office hours;
d. a training program.

NFR 19 In case of emerging new models after 2017, the Ringtoets development version will be separated from the product version, by using branches in the version control system, in combination with version tags.

The system availability for a particular user will depend on the server or local PC on which Ringtoets and the databases are installed.

4 Functional Design – Use Cases

4.1 Introduction

The use cases, presented hereafter, intent to describe all different steps in the process of input, schematization and assessment, based on the detailed workflow in section 2.3.2 and based on the requirements in chapter 3. The interaction between the user and Ringtoets will be defined in terms of input, forms, GUI elements and output.

The use cases supply a basis for the technical design in chapter 5, and additionally define the required functionality, which needs to result from different implementation tasks. The description of the Use Cases and the technical design in chapter 5 both assume that the main window of Ringtoets will consist of a number of specific bars and subwindows. These windows and theire functions are depicted in Figure 4.1, and listed below.

- *Menu bar*: access to all supported tasks and settings
  NL: *Bestand/Bewerken/Beeld/Toetsen/Gereedschap/Help,*
  EN*: File/Edit/View/Assess/Tools/Help*
- *Tool bar:* quick access to often used tasks and settings
- *Data Filter*: for filtering the presented data in the different sub-windows, based on the selected data. By default, all is shown.
  - NL: *Data (Kerndata, Schematisatie, Resultaten, Alles)*
  - EN: *Data (Key data, Schematization, Results, All)*
- *Task Filter:* for filtering the presented data and available options, based on the selected activity/task. There are tasks for the computation of hydraulic loads and for the assessment of dikes, structures and dunes. The hydraulic load and the assessement computations are further specified for different mechanisms.
  - NL: *Hydraulische belastingen: Waterpeilen in uitvoerlocaties, waterpeilen in doorsneden, overslag debiet, overslag kruinhoogte, golfparameters.* EN: *Hydraulic loads: Water level in output locations, water level in cross section, overtopping discharge, overtopping crest level, wave parameters.*
  - NL: *Toetsen – dijken: Overslag, bekleding, stabiliteit binnenwaarts, piping.* EN: *Assessment – dike: Overtopping, revetment, stability inward, piping.*
  - NL: *Toetsen – constructies: Overslag, piping, stabiliteit, sterkte constructie, niet-sluiten.*
    UK: *Assessment – structures: Overtopping, piping, stability structure, Structure failure, Nonclosing of structures*
  - NL: *Toetsing – duinen*
    UK: *Assessment – Dune erosion*
  - NL: *Toetsen – combinatie*
    UK: *Assessment – Combination*
- *Assessment level:* For assessment levels for tasks (NOT for Hydraulic load):
  - NL: *Toetsniveau*: *Releventie (0), Eenvoudig (1), Gedetailleerd (2a), Probabilistisch(2b)*
    UK: *Assessment level: Relevance (0), Simple (1), Detailed (2a), Probabilistic (2b).*
- *Kaart/Map window*: for topview presentation of the location of objects, for focus selection of one or more objects, using selectable layers for viewing object groups. Standard GIS functions like zooming and panning are available as well. Other GIS functions, such as

graphically defining or modifying locations of points, lines and objects will not be supported, except for the graphical definition of the locations of mechanism sections.

- *Eigenschappen/Properties tabs*:
  - o for editing all properties of a focused object
  - o for editing settings for the project and for specific models and methods.
- *Lists and Charts section*
  - o *Object lists with Key data and Schematization data* The different tabs containing key data and schematization data are object lists, allowing the selection, adding, removing of objects or the editing of certain object properties.
  - o *Charts with Results.* The different tabs with *Results* are charts, containing a tabular and graphical presentation of input and results per cross section, or along the dikeline.
  - o The *Meldingen/Messages* list contains warnings and errors, with associated repair actions.
  - o The *Log Uitvoer/Log Output* list contains the progress information and statistics as produced during an assessment run

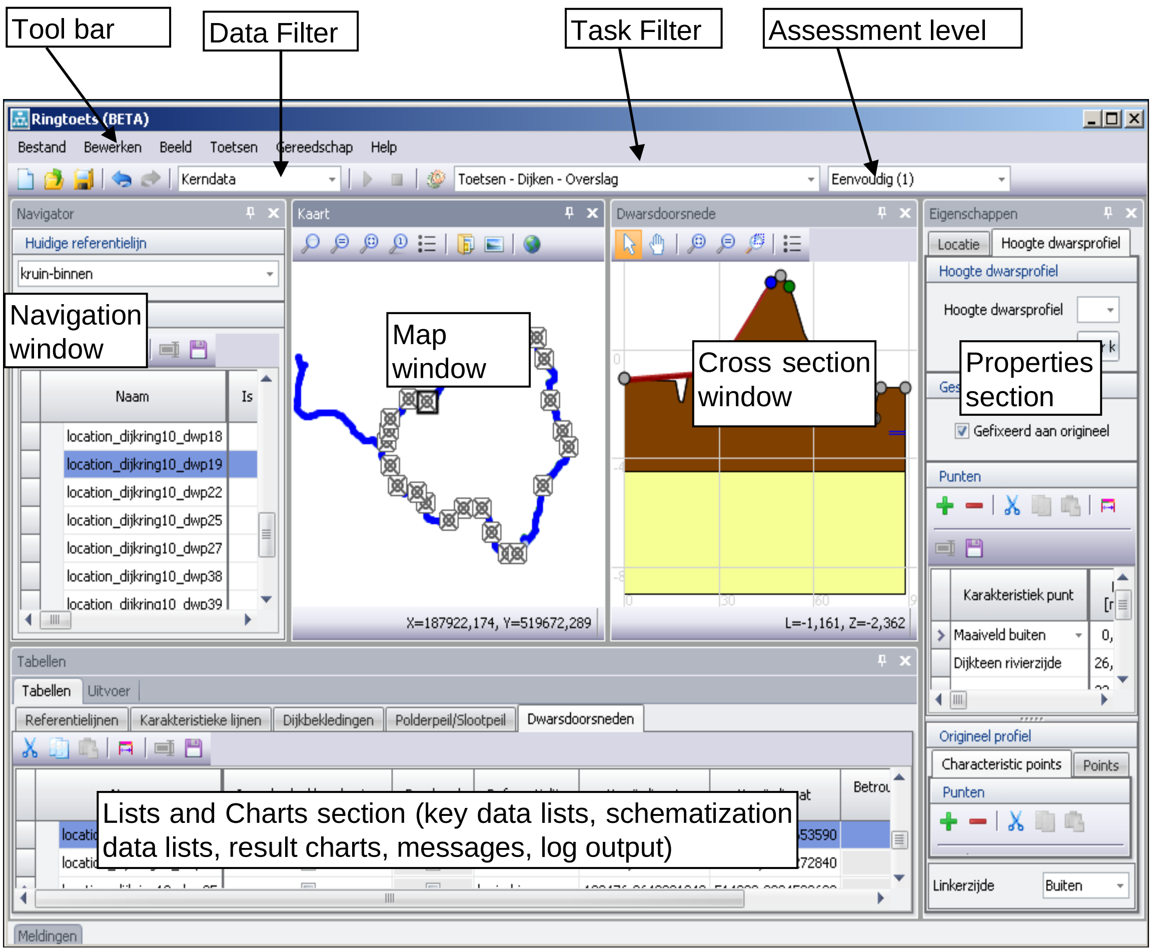


Figure 4.1 Components of Ringtoets User-Interface

Furthermore, the following concepts and rules apply to more than one case.

1 Ringtoets will allow for input or modification of the location of all objects in a tabular list and/or property window, and present the (modified) location in a map window.
2 Ringtoets will not support the graphical definition or modification of key data in the map itself, as the regular procedure will be to use a fully featured external GIS system for that purpose.
3 Ringtoets will support additional graphical definition of mechanism sections in the map itself, as this schematization task is primary executed in Ringtoets itself.
4 Each tabular object list and chart will have the option for import and export of CSV data, additional to import and output through XML on a system level.
5 User modifications to imported data in property window and in object lists will be recognizable by a different presentation.
6 Any data modification and all calculation results are first stored in the Ringtoets' memory. Only when a user invokes a *Save* command, the data are stored in central project database.
7 Each main item in the menu bar will preferably have only a single layer of sub menus. Sub menus will give easy access to data windows for data manipulation and to action forms for user invoked actions.
8 User invoked actions such as import, export and different calculations will be started from *action forms*, giving access to single or grouped actions as well as to related settings.
9 Settings for different calculation procedures and models will be accessible: (1) through a tabbed settings form: (2) through an easy access button on action forms.
10 For relevant settings and parameters that can change per cross section or mechanism section, Ringtoets will give the option to define global defaults, and then define per cross section whether these defaults should be overruled.
11 When a user changes input of certain parameters or settings, Ringtoets will automatically remove all already calculated results affected by this input. A subsequent calculation action will be limited to the (re)calculation of the missing part.

4.2 Installation of Ringtoets

Installation of Ringtoets starts with reading the installation manual and starting the program setup.

UC 1 **Install Ringtoets.** The system administrator downloads the installation software and associated manual from the download server or uses a CD-ROM. The system administrator reads the installation manual. This manual provides information on the setup procedure, project file names, hardware and network requirements for the Ringtoets application.

The system administrator starts the program setup of Ringtoets for installation on a local PC or on a Citrix server farm. The install program asks for: (a) a destination folder for the Ringtoets application and the selected hydraulic databases; (b) the selection of one or more hydraulic databases to install, from a list.
Finally, the setup checks the operating system (incl. version), physical requirements (access rights, disk space etc.), copies the program modules and selected hydraulic databases, adds a start-up icon in 'Windows start menu', etc. The program will ask the user to place a *Shortcut* on the Desktop (Yes and No button). At the end of the

installation, the program pops up a message box with a message of a successful installation, and asks whether the administrator directly want to open Ringtoets (or not).

UC 2 **Configure GIS connector(s)**. The basic Ringtoets installation will have a default, configured GIS-connector. The GIS-connector is necessary for the import of key-data. A *mapping table* relates the objects in different GIS files to the data objects required by Ringtoets. The system administrator can make (configure) a custom mapping table for different GIS databases with key-data. The system administrator can create a new mapping table for a custom GIS connector in the installation directory of Ringtoets, or by installing an already pre-configured file (for example for standardized IRIS data). The default installed GIS-connector will link to (standardized) IRIS data.

4.3 Getting started

UC 3 When starting Ringtoets for the first time, Ringtoets will open with an **example input**, equal to the example described in the tutorial part of the Users manual. The main structure of the menu bar of Ringtoets will show the following items: *Bestand/File – Bewerken/Edit –Beeld/View – Toetsen/Assess – Gereedschap/Toos – Help.* The user can access the Users manual via *Help > Handleiding/Manual.* The Dutch language manual contains, besides the tutorial part, also a reference part and a scientific part. The tutorial part supplies a step-by-step example description, covering the input and assessment process for different types of mechanisms and for different assessment levels. After reading this section, the user is aware of the steps to follow and the input data to supply. When starting Ringtoets thereafter, Ringtoets will open with the last opened project.

4.4 Create or open a project

UC 4 Optional: **setup access to a project database server.** In case of an intended project database on a remote server, the server administrator needs to grant access to the users which are allowed to create or modify the project database(s). A server location in a 'demilitarized zone' is required, if people from outside the local area network need to have direct access[11].

UC 5 After each start of the program, Ringtoets will check the software version plus hydrodynamic databases (including the output locations database) and give a warning if they are not available or out-of-date. An internet connection is required for this functionality. The user can now create a **new project**. In the menu bar he selects *Bestand/File > Nieuw/New*. Ringtoets opens a dialog where the user must define a project name and select the location of the project. After confirmation, Ringtoets will create and configure the project database in the designated location.

UC 6 The user that has defined a new project has also to define the **project settings**. The project form, which is displayed when the user selects *Gereedschap/Tools > Opties/Options*, provides the possibility to define the project settings as defined in par 5.6.4.

11. *If the central Ringtoets project database is not accessible outside the local area network, then it is still possible to share project data manually, by using the import of XML files (UC 46).*

UC 7 Each user can open an **existing project**. In the menu bar, the user selects *Bestand/File* > *Openen/Open…* Ringtoets opens a dialog in which the user can select a certain project database in a local folder, on a LAN folder or on a remote server. Ringtoets will load the project data and show the objects in the Map window.

UC 8 **Intermediate save**. At any time during the session, the user can select from the *Bestand/File* menu the commands *Opslaan/Save*, *Opslaan als* / *Save a*s.

UC8.a The *Opslaan/Save* command will cause an intermediate save of the project data to the project database including all changes and calculation results. Untill that moment, the data changes and any calculation results are only stored in Ringtoets' memory and are not part of the project database yet.

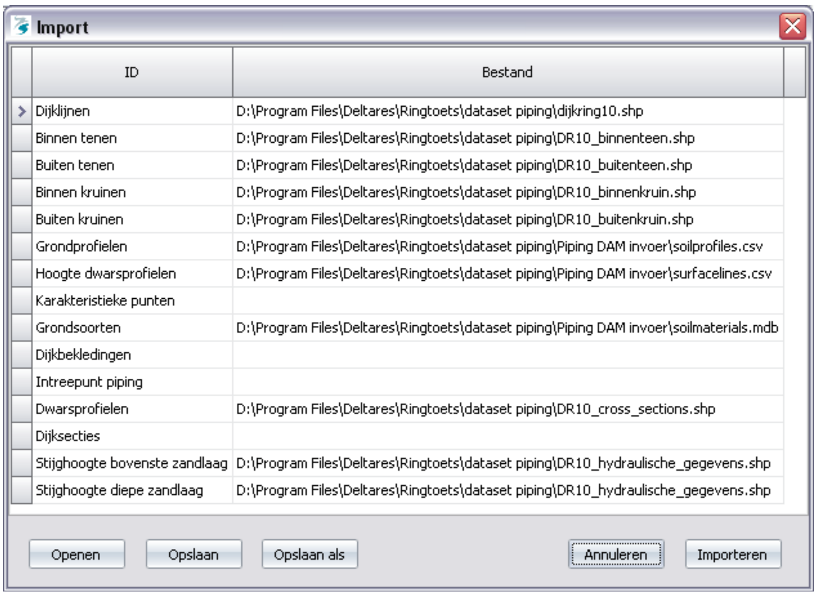
UC8.b After the *Opslaan als / Save A*s command, Ringtoets writes a full project database including the latest changes and calculation results under a new user-defined name and/or folder location.

UC8.c Ringtoets will have an *Auto Save* function which frequently saves the changes and calculation results since the last normal save to a recovery file. The auto save function will not save to the database. If Ringtoets terminates in an exceptional manner, the recovery file is used restore the previous session after a restart. The same kind of recovery file is used when exporting latest changes (UC 46).

4.5 Import of key data

When starting a new project, the user will usually import key data from existing GIS based databases or from archived project data. Key data includes all already processed data that is required for assessment. Examples of key data are the dike line, the cross section surface, the structures in the dike system, the revetment data and the subsoil library.

UC 9 In the menu bar, the user will choose *Bestand/File > Importeren/Import*. Ringtoets opens the *Importeren/Import* dialog, where the location, type and name(s) of the files can be specified. The supported file types are: (a) XML files; (b) shp and csv files.



The shp files are a “snap shot” of the databases maintained with GIS by the water boards. The subsoil csv files are a snapshot from a MDB database, maintained with the *DSoilModel* software.

According to the more detailed use cases in section 4.6, Ringtoets can import the following key data from one or more XML files:

UC9.a Dike line (referentie lijn).
UC9.b Characteristic lines (karakteristieke lijnen)
UC9.c Structures (kunstwerken)
UC9.d Breakwaters (golfbrekers)
UC9.e Revetment (bekleding)
UC9.f Piezometric heads and inland water levels (stijghoogtes en polderpeilen)
UC9.g Surface lines (hoogte dwarsprofielen)
UC9.h Subsoil data (grondprofielen + grondsoorten).

UC9.i XML files allow exchange of user input or reuse of archived input. In this case, links to modified or deleted data objects could be broken. To prevent that, Ringtoets will strictly check all imported XML files on broken or non-existing links. If a broken or non-existing link is detected, Ringtoets will give a warning and decline the entire import file.

UC9.j If the user selects a SHP or CSV source, Ringtoets will show which files with their pre-configured names (UC 2) are available at the specified location. The import dialog will ask for names of all the required files. Ringtoets will use the configured mapping table to connect the data items in the different files to the Ringtoets data items.

UC9.k A user can select a “read” or add mode for import of XML, SHP and CSV files. In case of the “read” mode, Ringtoets will clear all existing input tables before importing data from the selected source. In case of the “add” mode, Ringtoets will add new database tables, and give a warning when a certain table is already available and data will be overwritten. Ringtoets will import all available data in the selected source file(s). Ringtoets will check the used reference system of the data source and transform it to a default geographic reference system.

UC16.a and others will show how Ringtoets offers also import facilities via CSV files on a lower level, by user selection of the corresponding CSV file from within one of the specific object lists, input tables and property window forms.

4.6 Input or modification of key data

This section describes optional modifications to the imported key data, or manual input of the key data. Basic functions are adding, selecting, moving or viewing objects. Modifying includes showing of object properties, editing or input of data, adding or deleting objects, selecting objects, moving or copying objects. For all uncertain input variables for strength models, Ringtoets will allow input of a distribution type and distribution parameters such as a mean value and a standard deviation, and present the design value. The latter is used in a level 2a analysis, and derived by using a partial safety factor.

UC 10 The **dike line** (referentie lijn) is the geometrical ‘backbone’ of the schematization per cross section and mechanism. The dike line is a line element consisting of (multiple bending) points. Ringtoets will only allow for manual input or modification of one or more dike lines at the initial stage, before any other input or import of key data has taken place. After selecting *Beeld/View > Tabellen/Tables > Referentielijnen / Dike lines* from the menu bar, the user is able to define or modify the points defining the dike line, via the property window.

UC 11 The **characteristic lines** (karakteristieke lijnen) along the dike line define the horizontal location of characteristic points in different cross sections. Examples of such help lines include: (from water side to land side):

- start voorland / start foreland,
- Intredepunt piping / entrance point piping,
- buiten teen / outer toe,
- start buitenberm nr *i*. / start outer berm nr *i*,
- einde buitenberm nr. *i*./ end outer berm nr *i*,
- buiten kruin / outer crest,
- binnen kruin / inner crest,
- binnen teen / inner toe
- start sloot / start ditch
- einde sloot / end ditch

etc. The object list with characteristic lines and property window are displayed via the *Beeld/View > Tabellen/Tables > Karakteristieke lijnen / Characteristic lines* command from the menu bar.

UC 12 Relevant **structures** (kunstwerken) are defined, either as a point, as a line or as an area, depending on the type of structure. The object list with structures and the property window are displayed via the *Beeld/View > Tabellen/Tables > Kunstwerken/Structures* command from the menu bar. In the map window, different types of objects are marked differently (e.g. circle, diamond etc.). The user can select structures, add or remove structures. Part of the structure properties will be specific for mechanisms.

UC 13 **Breakwaters** (golfbrekers) like caissons, dammen / rubble mounds and verticale wanden / vertical walls can be edited in a properties window after selection of a breakwater in table or map. The object list with structures and the property window are displayed via the *Beeld/View > Tabellen/Tables > Golfbrekers/Breakwaters* command from the menu bar. In the map window, different types of objects are marked differently (e.g. circle, diamond etc.). The user can select breakwater structures, add structures or remove structures and change the properties of the structures.

UC 14 **Revetment** (bekleding) can consist of different zones along a cross section, each zone spanning multiple cross sections. Every revetment zone has its own revetment properties. The revetment zones locations and properties are usually imported, but they can also be defined or modified by the user.

UC14.a The available revetment zones are listed in a Bekledingzones / Revetment Zones List, with the last added ones by default in front. New zones can be added to or removed from that list with the help of buttons. A user can select a revetment zone in that list and then edit the properties in a Properties window. The required properties depend on the revetment type and subtype and on the mechanism model. It is possible to select a Revetment Zone in the List and use the *Copy* button to make a duplicate with a new name, and initially the same revetment properties.

UC14.b Revetment in the map. The user starts by selection via the menu bar *Beeld/View > Tabellen/Tables > Bekledingszones / Revetment Zones*. The location of the available revetment zones will be shown in the map window via colour lines along the dike line. The user can edit the revetment features and properties in the map.

UC 15 For the purpose of a uplift/heave/piping assessment: Add or modify the **inland piezometric heads** (stijghoogtes) and **inland water levels** (polderpeilen) along the dike line, after selecting the *Beeld/View > Tabellen/Tables > Stijghoogtes / Piezometric Heads* and the *Beeld/View > Tabellen/Tables > Polderpeil / Inland water levels* command from the menu bar. The object list will show the available sets, consisting of an upper and lower limit for both the piezometric heads and the inland water levels. Ringtoets will display already imported or inputted piezometric heads and inland water levels in the chart window, as a function of the dike line coordinate, in a graph or in a table. The user can add, delete or modify points and values in this table. The graph will show the name labels of location points along the dike line at certain distances. The user can modify or extend the piezometric data table when required.

UC 16 After selecting the *Beeld/View > Tabellen/Tables > Dwarsprofielen / Cross Sections Surface* command, the user can add or select a cross section via a cross section object list or via the GIS map. The *Dwarsdoorsnede / Cross Section* window shows graphically the selected cross section surface line, including the cross section name and the characteristic points. For good readability the surface line diagram has a horizontal and vertical fixed axis and clear marks of the characteristic points. Zoom and panning tools are available as well.

UC16.a In the *Eigenschappen / Property* window, the user can define (in case of manual input) or modify (in case of already imported key data) a **surface line**, defining the relevant part from the water side to the land side. Instead of manual input of a single surface line, the window offers also the possibility to import the list of coordinates locally, from a CSV file. He can also add a new point. Ringtoets will redraw the surface line. The cross section editor's axes system is LZ oriented. L is perpendicular to dike line. Ringtoets automatically translates the LZ-coordinates to XYZ (RD)-coordinates in the map, and vice versa.

UC16.b In the *Dwarsdoorsnede* / *Cross Section* window, the characteristic help lines (UC 11) are displayed as verticals. Ringtoets can use these lines to determine the associated **characteristic surface points** (karakteristieke punten) automatically. The user can graphically select one or multiple surface line points and move or delete them. The user can define or redefine the location of characteristic points manually, by dragging them to the desired surface points.

UC16.c In the *Cross Section* window, the initial **revetment zone locations** are projected on the surface line. The user can adjust the initial location manually by dragging the revetment zone boundaries horizontally. Ringtoets will give a repair action if the revetment zones do not cover the whole surface from outer toe to outer crest.

UC 17 For an uplift/heave/piping assessment: Select the *Beeld/View* > *Tabellen/Tables* > *Grondprofielen / Soil profiles* command from the menu bar, to add or modify **Subsoil profiles** (grondprofielen). Select the *Beeld/View* > *Tabellen/Tables* > *Grondsoorten / Soil parameters* command from the menu bar, to add or modify **Subsoil parameters** (grondparameters). Editing and presentation options for the subsoil data will be completely equal to the options provided by the *DSoilModel* application.

When a sub soil library has already been imported or defined, then the available 1D or 2D soil profiles, soil types and soil type properties for piping and slope stability will be available as a start, together with a definition of the stretches (segments) along which one or more subsoil profiles are valid.

UC17.a A user can define soil materials in the object list window and edit properties in both the object list window and the properties window.

UC17.b A user can add, delete and edit the different segments along the dike in the Object list window. The 1D or 2D soil profiles connected to a certain segment are visualised in the Cross section window.

UC17.c A user can define or change the soil profile geometry in the properties window. The soil profile geometry must comply with the constraints posed by the piping model to be used (a cluster of cover layers, combined with one aquifer layer. The horizontal 2D cross section coordinate is defined relative to the dike location line (LZ-coordinates instead of RD-coordinates).

The required soil properties for a level 1 heave/piping assessment are only the cover layer thicknesses and densities. The required additional soil type properties for a level 2 heave/piping assessment may include the dimensions and physical properties of one or two aquifers.

UC 18 **Multi-user edit**. Ringtoets will have multi-user functionality. This means that multiple users can work simultaneously on one project, by using storage of project data in a central project database with multiple user access.

UC18.a If a certain user has made nonsaved changes to certain key data or schematization data, this data will automatically be locked for editing by others. The lock will automatically be released after a save to the database. The locking of data is necessary to prevent data inconsistency. When setting focus to an already locked object, the user will be warned that modification is not possible. Another (nonpreferred) method for working simultaneously is to work on local databases (UC 46).

UC18.b Ringtoets will automatically lock blocks of data (both key data and schematized data) when a user starts assessment calculations that need to use this data.

4.7 Schematization for hydraulic boundary conditions, including overtopping

UC 19 **Activity and Data Filtering for hydraulic boundary conditions**.

UC19.a Selecting *Toetsen/Assess > Taak/Task > Hydraulische belastingen / Hydraulic load* or using the equivalent activity filter option, optionally followed by selecting *Toon Data > Schematisatie / Show Data > Schematization*, will limit the visible data and options to those required/available for schematization of Hydraulic boundary conditions.

UC19.b Ringtoets will show in the messages window (and/or the tentative workflow window) which schematization actions the user needs to perform before a run can start.

UC 20 **Linking cross sections to output locations**.

UC20.a Selecting *Beeld/View > Tabellen/Tables > Dwarsdoorsneden / Cross sections* will activate the object list with cross sections. After selecting the *Auto-verbind uitvoer locaties / Auto-link output locations* option for one or more cross sections, Ringtoets will automatically connect these cross sections to the nearest output location, with search paths restricted to the waterside. The resulting links will be visible in the table, as well as in the map window. If the distance to the nearest output location exceeds a certain threshold, Ringtoets will give a warning and not link that cross section.

UC20.b The thresholds can be altered by the user in a settings tab.

UC20.c Ringtoets will automatically repeat the automated linking for a selected cross section when the location of that cross section changes.

UC20.d The user can manually establish or modify links in the list, by first unselecting the *Auto-Link* selection for a cross section and then selecting one or two output location id's from a list. In case of a connection to two output locations, the user has to specify the relative contribution of the second location. The user can also remove links.

UC 21 **Linking cross sections to breakwaters**

Selecting *Beeld/View > Tabellen/Tables > Dwarsdoorsneden / Cross sections* will activate the object list with cross sections. The user can manually establish or modify a link between a cross section and a breakwater in the list, by selecting a breakwater location id from a list. The user can also remove links. The resulting links will be visible in the map window.

UC 22 All hydrodynamic databases in 2017 are expected to contain directly the wave parameters that are required for a revetment and overflow/overtopping assessment. The databases of most regions in 2006 and 2011 however, do not yet supply these wave parameters. Therefore, Ringtoets has to support temporary the import and/or input of **fetch area** (strijkvak) parameters for selected output locations, for the wave generation model according to Bretschneider.

UC22.a Selecting an output location will give access to the *Strijkvakken / Fetch areas* tab in the Properties window. In this window, the user defines a *bodem ligging / bottom location* and a *strijklengte / fetch length* for different wind directions. The number of shown wind directions is therefore 12 or 16, depending on the hydraulic load region in which the connected output point is located.

UC22.b Ringtoets displays the inputted fetch areas for all wind directions and output locations in the map window.

UC 23 View or input other **Hydraulic Load parameters and settings.**

UC23.a Selecting the command *Toetsen/Assess > Instellingen/Settings* will give access to a *Instellingen / Settings* tab in the Properties window, to view the following non-editable **Hydraulic Load settings**.:

X	Omschrijving	Een-heid	Type	Parameters		Ruimtelijke spreiding		Variatie in de tijd	
				ligging	spreiding	d_x	ρ_x	Δ_t	ρ_t
Δd	fout in bodemligging	m	nor	0,0 m	σ = 0,30 m	900 m	0	1 jaar	0,5
mgH	modelfactor Bretschneider voor Hs	-	log	1,0	σ = 0,15	900 m	0,7	-	1
mgT	modelfactor Bretschneider voor Ts	-	log	1,0	σ = 0,15	900 m	0,7	-	1
Δhloc	fout in lokale waterstand	m	nor	0,0	σ = 0,15	6000 m	0,5	-	1
*β**	afwijking golfrichting	o	nor	0,0	σ = 20o	vak	0	1 jaar	0,5
ts	stormduur	uur	log	7,5	V = 0,25	-	1	12 uur	0
P1	Model factor overslag, golfoploop 1	-	Det	1,75					
P2	Model factor overslag, golfoploop 2	-	det	4,3					
P3	Model factor overslag, golfoploop 3	-	det	1,6					
P4	Model factor overslag voor brekende golven.	-	det	4,3					
P5	Model factor overslag voor niet-brekende golven.	-	det	2,3					
P6	Model factor overslag voor ondiepe golven.	-	det	0,21					

The stochastic properties are the following:

(1) verdelingstype/ distribution type (deterministisch/deterministic or normal/normal or lognormal/lognormal);
(2) verwachtingswaarde / mean value
(3) standaardafwijking / standard deviation or variatie coefficient / variation coeffient;
(4) correlatie lengte / correlation length;
(5) ruimtelijke restcorrelatie / spatial correlation coefficient rho_x;
(6) correlatieperiode / correlation period
(7) restcorrelatie voor de tijd / temporatal correlation coefficient rho_t.

Contrary to PC-Ring, Ringtoets will not give the option for input of auxiliary user-defined Hydraulic Load parameters, in case these parameters are not part of the hydraulic boundary conditions database. These auxiliary parameters are specifically: a *golfhoogte / wave height* and *golfperiode / wave period* per wind direction for deining/swell and a combined *water level opzet/setup* for the effect of seiches/squall..

UC 24 For the purpose of an **overflow/overtopping/revetment** assessment per cross section: Select the cross section in the Navigator window. The *Overslag Profiel/Overtopping Profile* tab in the Properties window will give the possibility to define a schematized surface line for the selected cross section[12]. Ringtoets will display in the cross section window the selected cross section surface (UC16.a) with characteristic points and revetment zone locations (UC16.c).

UC24.a The automated schematization proposal by Ringtoets is already invoked for all applicable cross sections when a user selects the *Toets/Assess > Taak/Task > Hydraulische belasting / Hydraulic load* option. A cross section is applicable for automated schematization if no schematized overtopping surface is available yet. Ringtoets uses characteristic points and revetment boundaries for this automated schematization. The user views the results of this proposal in the table.

UC24.b The user views the schematized profile also in the cross section window.

UC24.c The user views the repair actions in the messages window for the selected cross section when automatized schematization is not possible. A repair action is required when the constraints to the geometry for foreland and dike are not met..

- The schematized profile must comply with the overflow/overtopping model constraints for a deterministic geometry definition according to the Hydra software (see section 5.7).
- Ringtoets will check if the schematized surface contains a foreland, by using the characteristic points defining the foreland start and end. Ringtoets will check if the schematization of the foreland complies to the foreland model constraints (e.g. slopes steeper than 1 to 10 are not allowed, etc. (section 5.7)) and give a message if not.

UC24.d The user inputs or modifies the coordinates and roughness's of the segments of the surface line in the list, wherever required.

4.8 Calculate hydraulic boundary conditions and overtopping per cross section

The probabilistic calculation of the hydraulic boundary conditions per cross section is required for a subsequent (semi-probabilistic) level 1 or level 2a assessment. Calculation of these conditions at the schematized cross sections (task A2) is possible after linking cross section locations to output locations for hydraulic boundary conditions and after schematization of linked breakwaters, foreland and fetch areas.

UC 25 Ringtoets can calculate and/or display the **water level** with a certain exceeding probability, at both the output locations (river axis) and at the toe of selected cross section locations.

UC25.a In the menu bar, the user selects *Toetsen/Assess > Taak/Assessment > Hydraulische belasting/Hydraulic boundary conditions.* With *Toetsen/Assess > Instellingen/Settings* the *Rekeninstellingen/Calculation settings* tab opens in the properties window. In the *Toetspeilberekening/Water level computation* section of this tab it is possible to select whether the influence of foreland and relevant hydraulic parameters should be included during a calculation at the toe (*Voorland meenemen/Include foreland)*.

UC25.b Cross section selection for calculation of the water level is possible via the navigation window. By default, none of the cross sections are selected.

12. *Compared to PC-Ring, Ringtoets will not support the input of a stochastically defined surface geometry*

UC25.c After *Toetsen/Assess* > *Start/Start*, Ringtoets will calculate the water levels at the selected output locations and the selected cross sections with linked output locations. Ringtoets will interpolate the calculated water levels along the dike line, in order to find values for the other cross sections. This enables a subsequent level 1 assessment at these cross sections without the need to compute the hydraulic boundaries for each cross section. *Start* is only enabled, if not all required results are available already.

UC25.d During the calculation, a progress indicator will display the progress, while warnings, log messages and error messages will be written to the *Meldingen/Messages* table.

UC25.e The calculation results are initially only stored in the Ringtoets' memory. Only after a user invoked *Save* command the calculation results are saved to the project database.

After the calculation has finished, the following results will be available as chart tabs:

UC25.f The resulting graph along the dike reference line displays the distribution of the calculated characteristic water level (toetspeil) at the output locations (river axis) and at the toe of all cross sections (if available), as well as the value of the water level with an exceeding probability which is ten times higher. The names of different cross sections are added to the x-axis of the graph, at certain distances.

UC25.g For a selected cross section or output location, Ringtoets will also present a table or graph of the water level (including the characteristic water level) as a function of exceeding frequency. Location selection will be possible via the map, or from a list. Output should also include the value of the difference between the characteristic water level (toetspeil) and the water level at a ten times higher exceeding frequency (decimeringshoogte).

For all water levels with different exceeding probabilities at different locations, RIngtoets will offer also the associated reliability index and design point value(s) as output. Each design point is defined by the values of the stochastic variables in the design point, optionally per wind direction.

UC 26 Ringtoets can calculate and/or display the **wave parameters** for a revetment assessment at the toe, for different water levels along the slope, and for different wind directions.

UC26.a In the menu bar, the user selects *Toetsen/Assess* > *Taak/Assessment* > *Hydraulische Belasting/Hydraulic Boundary Conditions.* With *Toetsen/Assess* > *Instellingen/Settings* the *Rekeninstellingen*/*Calculation settings* tab opens in the properties window. The *Golfparameters/Wave parameters* section of the form will give the possibility to set whether the influence of foreland or breakwaters should be included, as well as the influence of different hydraulic parameters. Ringtoets will calculate the wave parameters from the design point of a dedicated revetment strength limit state function, similar to the Hydra software, see also FR 39c.

UC26.b Cross section selection for calculation of the wave parameters is possible via the navigation window. By default, none of the cross sections are selected.

UC26.c After *Toetsen/Assess* > *Start/Start*, Ringtoets will calculate the wave parameters for different water levels at cross sections with linked output locations. Ringtoets will interpolate the calculated wave parameters along the dike line, in order to find values for the other cross sections. This enables a subsequent level 1 assessment at these cross sections for different failure mechanisms, without the need to compute the wave parameters for each cross section. Selecting *Start* will only be possible, if not all required results are available already.

UC26.d During the calculation, a progress indicator will display the progress, while warnings, log messages and error messages will be written to the *Meldingen/Messages* table.

UC26.e The calculation results are initially only stored in the Ringtoets' memory. Only after a user invoked *Save* command the calculation results are saved to the project database.

After the calculation has finished, the following results will be available as chart tabs:

UC26.f For a selected cross section or output location, Ringtoets will present a table or graph for each characteristic wave parameter (wave period, wave height) at the toe as a function of the water level, for different wind directions. Cross section location selection will be possible via the map, or from a list. For each level in the table, Ringtoets will also present the design point (illustratiepunt) of the stochastic variables, optionally per wind direction. Ringtoets will additionally give the associated wave parameters at the toe and at the start of a foreland and/or a breakwater, when applicable.

For all calculated wave parameters with different exceeding probabilities at different locations, Ringtoets will offer also the associated design point value(s) as output. This means the values of the stochastic variables, optionally per wind direction.

UC 27 Ringtoets can calculate and/or display **overtopping** results per schematized cross section.

UC27.a In the menu bar, the user selects *Toetsen/Assess > Taak/Assessment,* and *Toetsen/Assess > Spoor/Mechanism > Overslag/Overtopping.* To open the overtopping calculation settings select *Toetsen/Assess > Instellingen/Settings* and the *Overslag/Overtopping* window opens in the property window. In this form it is possibility to select whether the influence of foreland or breakwaters should be included, as well as the influence of different hydraulic parameters.

UC27.b Cross section selection for calculation of overtopping discharges is possible via the navigation window. By default, none of the cross sections are selected.

UC27.c After *Toetsen/Assess > Start/Start*, Ringtoets will start the overtopping calculation. Ringtoets will calculate the overtopping discharges at cross sections with linked output locations and with schematized cross section surface. Ringtoets will interpolate the calculated results along the dike line, in order to find values for the other cross sections. Clicking the Selecting *Start* will only be possible, if not all required results are available already.

UC27.d During calculation of missing results, a progress indicator will display the progress, while warnings, log messages and error messages will be written to the *Meldingen/Messages* table.

UC27.e The calculation results are initially only stored in the Ringtoets' memory. Only after a user invoked *Save* command the calculation results are saved to the project database.

After the calculation has finished, the following results will be available as chart tabs:

UC27.f At a selected cross section: a table or graph of different crest levels with associataed different probabilities of exceeding a user-selected critical overtopping discharge (default equal to 1 m^2/sec). This chart is called: *hydraulisch belastingniveau*.

UC27.g Along the dike reference line: a table or graph of the actual crest level and the required crest levels (the levels where a user-defined critical overtopping discharge is equal to different user defined exceeding probabilities).

UC27.h Along the dike reference line: the characteristic overtopping discharge with a specified exceeding frequency, calculated at the actual crest level.

For all calculated values of height or discharge with different exceeding probabilities at different locations, Ringtoets will offer also the associated design point value(s) as output. This means the values of the stochastic variables, optionally per wind direction. Ringtoets will additionally give the associated wave parameters at the toe, including the amount of reduction caused by breakwaters and/or foreland.

4.9 Schematization for level 1 assessment of height and stability

This section describes the definition or modification of the additional data required for a level 1 assessment of the different stability mechanisms per cross section. A level 1 assessment uses geometry based decision rules to decide if a more detailed assessment is required or not. Modifying includes showing of object properties, editing or input of data, adding or deleting objects, selecting objects, moving or copying objects.

UC 28 Selecting the **task filter** *Level 1* in combination with selecting the task filter for the appropriate mechanism will limit the required input and options for all mechanisms to the required assessment level.

UC 29 For the purpose of a level 1 or level 2 **uplift/heave/piping** assessment, different schematizations are possible, depending on the available data.

UC29.a Selecting the *Toetsen/Assess > Piping Dijken / Piping Dikes* command from the menu bar will show the relevant tables and options for Piping. For a selected cross section, Ringtoets will display the selected surface (UC16.a) in the cross section window, together with the connected sub soil profile(s) (UC 17), the polder level and the ‘inland piezometric head’. If the number of connected soil profiles is larger than 1, then a probability of occurrence for each scenario must be available.

UC29.b The initial location of the piping entrance point in the cross section follows from a characteristic line (UC 11), and can be modified by the user. If no characteristic line is available, then Ringtoets will assume that the entrance point is located in the outer toe.

UC29.c If no subsoil data is available, then Ringtoets will use as a conservative assumption that the exit point is located at the inner toe, and that uplift and heave will occur.

UC29.d If subsoil data is available for the considered cross section, then Ringtoets will use a procedure similar to the DAM software to check if uplift and heave can occur, assuming that a damping factor of zero and an infinite leakage length. In this conservative case, the required minimum factor of safety for uplift is 1. Ringtoets will use a minimally required FoS and the weight and thickness of the cover layers to check if uplift can occur [Lit 6.14], [Lit 6.15]. If the answer is true, Ringtoets will also determine the location of the exit point en check if heave at that location can occur.

UC29.e Ringtoets will graphically display in the cross section window the resulting distribution of pore pressures and cover layer weight from the inner toe to the polder side, together with an indication of the exit point (the first location where the FoS for both uplift and heave are smaller than the minimally values).

UC 30 **Export/import project data for a level1 assessment**. For the purpose of data exchange, the user can export the project data for a level 1 assessment via the *File > Export* command. Another user can import this data via the *File > Import* command, in order to create an exact project database copy.

4.10 Execute level 1 assessment for height and stability

When the input for level 1 is completed and when the hydraulic boundary conditions and overtopping results are calculated per cross section, the user can start the level 1 assessment procedure on cross section level.

UC 31 **Perform a level 1 assessment** (task A3/A4).

UC31.a In the menu bar, the user selects the mechanism *(toetsspoor*) and the assessment level 1 (e*envoudig*).

UC31.b Cross section selection is possible via the navigation window. By default, all valid cross sections are selected.

UC31.c The user inspects the input data and applies modifications when required.

UC31.d After clicking the *Run* button, Ringtoets will execute a level 1 assessment per selected mechanism and cross section, based on geometric dike characteristics. Clicking the *Run* button will only be possible, if not all required results are available already.

UC31.e During assessment, a progress indicator will display the progress, while warnings, log messages and error messages are written to different tabs of the messages window.

UC31.f The assessment results are initially only stored in the Ringtoets' memory. Only after a user invoked *Save* command the calculation results are saved to the project database.

The following results will be available after the assessment calculation is completed.

UC31.g The available results for all assessed mechanisms are displayed in the map window for all cross sections along the dike ring. The user can change the selected mechanism via a drop down box. Each cross section will show per selected mechanism an indicator of the required assessment level (0, 1 or 2), see Figure 2.3. If overtopping results per cross section are available, the map view will also show indicate at which cross section the crest height of the cross section is sufficient.

UC31.h The available results are also presented in a chart tab. The table displays in the columns the cross section ID (name), the ring coordinate, and the required assessment level (0, 1, 2) per different stability mechanism. The table will also indicate in a number columns if the crest height of the cross section is sufficient with regard to different values of the overtopping criterion.

4.11 Additional schematization for level 2 assessment

The result of the level 1 assessment is per mechanism a dike line divided in stretches where the mechanism is irrelevant (0), where simple assessment is sufficient (1) or where a detailed assessment level (2) is required. The stretches marked with 2 are input for the detailed level 2 assessment, as described in this section. Input of additional soil and revetment properties for a detailed level 2 analysis will be analogous to UC 14 and UC 17.

UC 32 Selecting the assessment task *Level 2a* in combination with selection of the appropriate mechanism will limit the required input and options for the selected mechanism to the required assessment level.

UC 33 Specify user-defined parameters to calculate a piezometric distribution in the aquifer for the purpose of a piping assessment.

UC33.a Selecting the *Toetsen/Assess > Piping Dijken / Piping Dikes* command from the menu bar will show the relevant tables and options for *Piping*. For a selected cross section, Ringtoets will display the selected surface (UC16.a) in the cross section window, together with the connected sub soil profile(s) (UC 17), the polder level and the 'inland piezometric head'. If the number of connected soil profiles is larger than 1, then a probability of occurrence for each scenario must be available.

UC33.b The initial location of the piping entrance point in the cross section follows from a characteristic line (UC 11), and can be modified by the user.

UC33.c Ringtoets will use a procedure similar to the DAM software to define the location of the exit point and the piezometric head distribution in the aquifer for each subsoil scenario, with the help of a damping factor, a leakage length, a minimally required FoS and the weight of the cover layers [Lit 6.14], [Lit 6.15]. The default damping factor is 0.3, the default leakage length is infinite and the default minimum Fos for uplift is 1.2.

UC33.d Ringtoets will graphically display in the cross section window the resulting distribution of piezometric head and cover layer weight for uplift from the inner toe to the polder side, together with an indication of the exit point (the first location where the FoS for both uplift and heave are smaller than the minimally value.

UC33.e If no subsoil profile are available, then Ringtoets will assume that the location of the exit point is at the

UC33.f If there is an uplift location found and if the heave criterion at that location is also exceeded, then Ringtoets will perform a simple piping check,

UC 34 Define **mechanism sections** and link to a **characteristic cross section**. The dike line and the location of the cross sections is the same for all mechanism schematizations. However, the dike section division and the cross section configuration can be different for each failure mechanism. A dike section is defined by the ring coordinate of the begin and end of the section, implicitly encapsulating a group of one or more adjacent cross sections.

UC34.a The user select from the menu bar: *Schematize > Mechanism Sections*. The map window and list tab shows the required assessment level indicators per cross section, for the (via the data filter) selected mechanism (0, 1 or 2). The screen shows also the imported section divisions, when available.

UC34.b When a user wants to define a separate mechanism section for each cross section (implying that the mechanism section division is equal for all mechanisms), then Ringtoets must give the possibility to generate such a division via the action form.

UC34.c If there is no mechanism section per cross section generated, the user can select and mark groups of adjacent cross sections as level 1 and level 2 sections, either graphically in the map window or in a list tab for mechanism sections (the latter by entering a ring coordinate for the start and end point. For a decision on the required division, the user can use the previously calculated indication of the required assessment level per cross section, as well as an analysis of the spatial variability of boundary conditions, physical properties and geometrical properties. During this process, a user can deviate from the cross section indication, when he or she feels that this is allowed under the specific circumstances.

UC34.d After the cross section group selection or generation of mechanism sections, the user can modify the initial ring coordinate of each section boundary manually. Ringtoets will give a warning if the mechanism section length becomes small, compared to the mechanism length.

UC34.e When mechanism sections divisions are equal for two or more mechanisms, a user must have the option to copy a mechanism section list for one mechanism to a mechanism section list for one or more other mechanisms.

UC34.f The user links each mechanism section to a schematized characteristic cross section, either in the map window or in the mechanism section list tab. This applies to overtopping/overflow/revetment (see UC 24) as well as to heave/piping (see UC 29).

UC 35 **Inspect the default partial safety factors**. The *View* > *Defaults* menu gives access to a tabbed form, containing amongst others an overview table of the partial factors for the relevant strength and load parameters, in relation to the models for the selected/locked mechanism(s).

4.12 Execute level 2a assessment

Level 2a (task B3) is a detailed semi-probabilistic assessment. This assessment is per mechanism and per mechanism section. The mechanisms include all relevant stability mechanisms, in combination with preceding overtopping when relevant.

UC 36 **Perform level 2a assessment and inspect results.**

UC36.a In the menu bar, the user selects *Toetsen/Asses > Deterministisch (2a) / Level 2a*, after preceeding selection of the mechanism group (toetsspoor). Ringtoets will display a form to input the data relevant to the selected mechanism group.

UC36.b Mechanism section selection is possible via the navigation window. By default, all valid mechanism sections are selected.

UC36.c After clicking the *Execute* button, Ringtoets will execute a level 2a assessment for the selected mechanisms and sections. Clicking the *Execute* button will only be possible, if not all input and assessment levels are available already.

UC36.d During assessment, a progress indicator will display the progress, while warnings, log messages and error messages are written to different tabs of the messages window.

UC36.e The assement results are initially only stored in the Ringtoets' memory. Only after a user invoked *Save* command the calculation results are saved to the project database.

The primary output of the computation is a FOS (factor of safety) or another mechanism dependent safety indicator for all available mechanism sections. The following results will be available after the assessment calculation is completed.

UC36.f The map window will show the FOS in all calculated sections for the selected mechanism. The user can change the selected mechanism.

UC36.g Tables or graphs of the FOS for one or more selected mechanisms along the dike line will be given also.

Ringtoets will display the combined results of different mechanisms on so-called combination sections, after selection of the combination from the mechanism list.

UC36.h The map window will give an overview of the combination sections where the FOS is sufficiently large for a level 2a assessment.

UC36.i A list tab of the combination sections will give the same results.

Mechanism specific detailed output per mechanism section will be available also, as far as required for tracing back the reliability of the computed FOS. The specific output is mechanism dependent.

UC36.j An example for piping is a graph along the dike line of the minimally required piping length versus the actual piping length.

UC36.k Another example for uplift/heave/piping is a graph of the actual characteristic water level (toetspeil) versus the allowed external head.

4.13 Additional schematization for level 2b assessment

Level 2 dike sections that do not pass a level 2a assessment are automatically input for the level 2b assessment (fully probabilistic check). For level 2b additional information per mechanism is required.

UC 37 Selecting the **data filter** *Level 2b* in combination with selection the data filter for the appropriate mechanism will limit the required input and options for all mechanisms to the required assessment level.

UC 38 **Optional stochastic subsoil model for piping**. The user can re-use the characteristic sub soil model (sub soil layers and materials) from level 2a, or switch to a stochastically defined subsoil model. For the latter purpose, the user can select the *Schematize > Piping* command, and check the “*Use sub soil scenarios*” check box in the properties window. The dike stretches along which a certain set of probable subsoil profiles (scenarios) is valid, as well as the probabilities of the different scenarios along that stretch, can be defined manually by the user in the list or properties tab, or the required information can be directly imported from an external database which also contains the subsoil library. Ringtoets will automatically connect the subsoil scenarios along a stretch to the sections in that stretch, and give a warning if a single section is part of two or more subsoil stretches.

UC 39 **Define presentation sections**. A presentation section is a part of the dike line used to calculate the combined failure probability for all selected mechanisms. The user activates the *Presentation Sections* form, via a menu bar command. An initial GIS screen or table shows the combination sections resulting from a level 2a analysis, with FoS indication. Initially, Ringtoets will use every combination section as a presentation section. The user can join two or more combination sections to one presentation section via GIS or via a table.

UC 40 **Inspect and modify the default autocorrelation parameters in space and time**. The *View > Defaults* menu gives access to an overview of the different autocorrelation factors in space and time for the relevant strength and load parameters, in relation to the selected/locked mechanism(s). A user can modify one or more of these parameters when required[13].

UC 41 **Export/Import project data for a level2 assessment**. In order to share project data, one user can export the mechanism specific project data for the locked mechanism, and another user can import this data in a central database and then execute a level2a and level2b assessment.

4.14 Execute level 2b assessment

Perform assessment level 2b (task C1). Level 2b is a detailed probabilistic assessment. This assessment is per level 2 mechanism section and also for combined mechanisms and mechanism sections, on so-called presentation sections.

UC 42 **Perform level 2b assessment.** In the menu bar the user chooses *Assess > Level 2b*. A *Level 2b* form will open.

UC42.a After clicking the Select button, the form offers the possibility to select one or more available mechanisms and to select one or more available mechanism sections for either level 2a or level 2b assessment. The selected mechanisms are marked with a check symbol (√).

UC42.b After clicking the Settings button, the user can change the default settings for various calculation options, including the probabilistic method (including start method) and the calculation scheme. Additionally, the user can overrule the default settings per mechanisms section, when desired.

UC42.c After clicking the Calculate Mechanisms button, Ringtoets will calculate the separate failure probabilities contributions and the associated design points per mechanism section, for all selected mechanisms and mechanism sections, based on input for the detailed mechanism models.

UC42.d After clicking the Combine Mechanisms button, Ringtoets will calculate the combined failure probability and design point for all each of the selected presentation sections, using all available contributions from selected mechanisms and mechanism sections.

UC42.e During calculation, Ringtoets will present progress and log information via a progress window. Ringtoets will also write the log information to a log file which can be inspected at any time via the Show Log button from the Level 2b form.

UC 43 The user can inspect the **results per mechanism section** from the last executed level 2b assessment via the menu bar command *Assess > Level 2b*. The results for a selected mechanism are displayed for all selected mechanism sections. The user can change the selected mechanism via a drop down box. Toggling between a GIS view and a tabular presentation is possible. The Map window will show the dike line and the location of the dike sections and characteristic cross section.

UC43.a The primary output of the computation is a failure probability and a design point (values of stochastic variables) for all available mechanism sections.

13. *It is still under discussion whehter the user should be able to change those values.*

UC43.b Secondary output is the failure probability per failure mechanism.

UC43.c The log file contains additional intermediate results. These results include the different reliability indices and design points per wind direction, per revetment layer, per subsoil alternative, per cross section etc.

UC43.d Conditional failure probabilities for design parameters. For example, what is the remainig failure probability if the water level has a reached a certain level (optional Ringtoets functionality).

UC 44 The user can inspect the **results per presentation section** from the last executed level 2b assessment via a menu bar command.

- Ringtoets will display the combined results of different mechanisms on presentation sections, after selection of the combined option from the mechanism list. Toggling between a GIS view and a tabular presentation is possible. The combined result is a probability of failure (or reliability index) with a design point for each presentation section, as well as a total failure probability (or reliability index) for all available presentation sections.
- The output will also show the failure probability budget for stretches that are assessed at level 1 or level 2a, and the remaining budget that is available for the combined level 2b presentation sections.

4.15 Report and Export input and/or results

UC 45 **Report intput and results**

UC45.a After selection the menu bar command *View > Report.* A dockable report window will appear. This report will first give an overview of the most important input data and results, (it has to be decided which data this is) followed by tables with complete results for cross sections, mechanism sections, combination sections and presentation sections.

UC45.b The report can be written to different formats, including pdf and docx.

UC 46 **Export.** Via the menu bar command *File > Export*, the user starts the *Export* form. In this form, the user selects first an export destination (SHP, XML, CSV) and then chooses whether input, output or both need to be exported. This functionality is of use if project data is exchanged with users outside the organization (UC 1). Exporting and importing the latest changes is useful when working offline or parallel to a project. The latest changes are all data changes since the last Save of data to the central project database. When *working offline*, a user first makes a complete copy of the (online) project database and starts working on it in an offline environment. When he is finished, he exports the latest changes to the (original) online project database. When *working parallel*, a user makes a complete copy of the (online) project database and at the same time exports the latest (unsaved) changes. He then opens the copy of the project database and imports the latest changes. He now can work parallel (offline) to the original project. He can modify and change the model until he is satisfied with the calculation results. To use the changes het exports the latest changes from his offline copy and imports the changes to the online project database . The project manager must manage the data and file exchange to be sure that for example data is imported from the correct external user with the correct adjustments. Ringtoets can not see if a data file is the correct version or an older one.

- Export of input to an editable XML file enables archiving of input, as well as exchange of input data between different users.
- Export of input and results to XML facilitates also connection to external software, such as a potential dedicated report module for a presentation assessment schematization and results.
- Export of latest changes to XML files (changes made since last Save to project database). See also Import of Key data (section 4.5).
- Export of input and/or output tables to CSV files facilitates coupling to spreadsheet software.
- Export to SHP files facilitates update of key data in the waterboard GIS database, as well as storage of final assessment results.
- <u>Tentative:</u> Export the deterministic schematizations per cross section to stand-alone tools such as Steentoets, D-GeoStability, PC-Overslag etc. This facilitates examination of output details with the stand-alone tools, as well as usage of the schematizations for further analysis and design.[14]

4.16 Strip results from database and close the project

UC 47 When choosing *File > Clear results*, Ringtoets will remove the results from the database, after a final user confirmation. This is to be sure that storage of new and old results in one database is prevented.

UC 48 Intermediate saving of input is already described in UC 8. The user will finally invoke a Close form, directly or indirectly, before Ringtoets will actually exit.

- When choosing *File > Close* without intermediate save, the user can choose to a) save and accept the changes, b) go back to project database after last save and discard changes. Both actions require a final user confirmation.

When choosing *File > Exit*, Ringtoets will first switch to the Close form if unsaved changes exist.

14. *This feature will only be available for the new generation of stand-alone tools based on the Delta-Shell Light library*

5 Technical Design

5.1 Introduction

This chapter describes the technical design of Ringtoets, based on the functional design as described in the previous chapter. The intended reader for this chapter is the programmer of Ringtoets. The two purposes of this chapter are:

1. to define the required structure, prior to the actual development.
2. to serve as system documentation for future maintenance.

As already explained in section 1.3, this chapter will be further improved and detailed during the development periods.

5.2 System architecture

The global Ringtoets design has been depicted already in Figure 2.1. This design corresponds to the generic design of a new generation of dike strength software applications (Ringtoets, stand-alone VTV tools and DAM), as presented in Figure 5.1.

Each application in the collection of new generation software consists of the following four layers.

1 The control layer contains the data model and steers the execution of different tasks in the three other layers.
2 The User Interface (UI) layer enables presentation and manipulation of input data and results.
3 The I/O-layer connects the internal or external databases to the UI layer and business layer.
4 The business layer contains all functionality to derive the user-requested output from the user-supplied input.

12

13 All layers connect to libraries for the functions that are shared with one or more other applications, such as the stand-alone VTV tools and/or DAM.

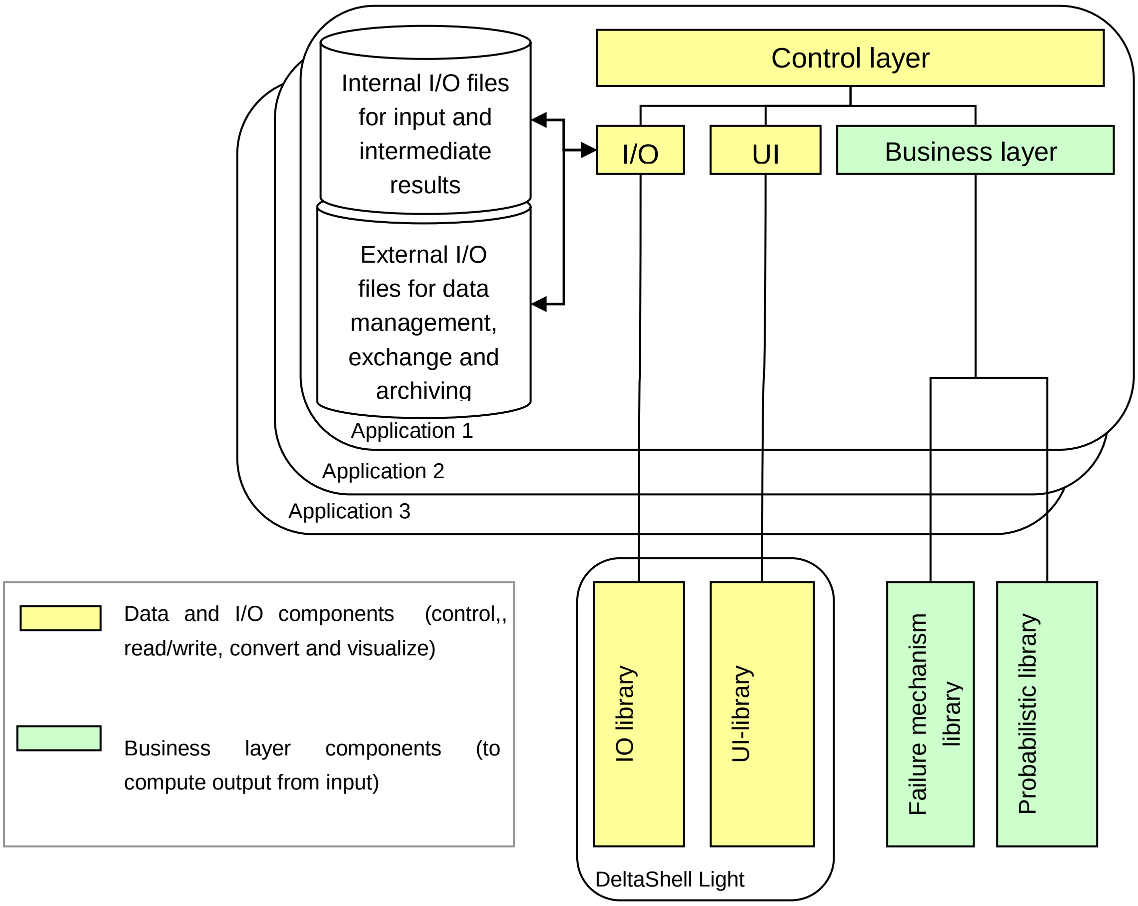


Figure 5.1 Generic architecture for the new generation of dike strength software

The supported tasks in the main control layer are depicted in Figure 5.2.

Figure 5.2 Technical design of the main control layer

The different Ringtoets packages (groups of software components) in the different layers are described below, and depicted in Figure 5.15.

Main Control Layer	
Ringtoets plugin	Code which brings all other components together, such as registration of UI components into the Delta Shell Light library
Business Layer	
Key data model	Contains all data and methods for the imported or inputted key data. Note that this package doesn't depend on any other package.
Assessment model	Contains all schematized data and results related to assessments on either cross section level or mechanism section level. This package will use HydraRing as one of its components.
Failure mechanisms	Library of all failure mechanism models
UI Layer	
Assessment UI	User interface components for the data in assessment model
Key and boundary conditions UI	User interface components for the key data in soil model
Delta Shell Light	Library with General facilities to build a user interface.
IO Layer	
Import and Export	Facilities to import and export project data to certain file formats (including the internal database format)

Figure 5.3 Software Packages

5.2.1 Modular User Interface design, with the Delta-Shell Light library

The Ringtoets UI an IO layers will be based on the Delta Shell Light library of software components, with a standardized look and feel. Delta Shell Light is a C# framework developed by Deltares and already used in different applications (DAM, D-SoilModel, Koswat, D-GeoStability).

The main philosophy behind the design of the Delta Shell Light components is that a user should be able to start with execution of his tasks without a steep learning curve. To accomplish this, the UI based on Delta Shell Light has the following features.

- A cross section editor and a map editor are placed centrally in the application.
- Besides the map and cross section editor, there are a couple of windows. Each window has its own way of presenting data. For example, there is a table section which displays data in tabular form. The same data can be presented on the map and/or a cross section. The following windows are available in Delta Shell Light:

Window	*Description*
Map window	Displays geographical located data. The map editor supports layers, which can be switched on and off on user request. The map editor is accompanied by a legend, which explains colours and symbols.
Navigation window	Displays a list with the most important objects to navigate to quickly and/or to select for specific actions. Often a list of locations is displayed here
Cross section window	Displays a cross section of the vertically arranged data in two dimensions, for example a sub soil cross section. The cross section editor supports layers and has a legend.
Report viewer	Displays a print preview of a report. A report can be printed or exported to a file format of choice.
Property window	Displays properties of a certain object, for example the selected object on the map or in a table. Depending on the type of object, there may be a different way of presentation. For example, a dike ring might contain a table of dike sections, a soil might have a long list with properties and a Q-h relation might display a small diagram.
List and chart section	Contains several tables and charts. All data which can be presented in a table can be displayed here. Also charts can be displayed, with or without connection with a table.
Messages section	Gives the user feedback about the data he has entered. This can be information about the validity of data or suggestions about which task to perform. For example, a message is displayed if a value exceeds the maximum allowed value. The suggested resolution is to assign the maximum allowed value, which will be performed on user request. The user will be able to start a calculation if all error messages have been resolved.
Output section	The output section is to be used for display of log messages generated by a calculation. The contents are purely informative for the user.

Figure 5.4 displays an example of a user interface based on Delta-Shell Light. This example shows that a map display, a cross section display, a property window, a table section and a feedback section are used.

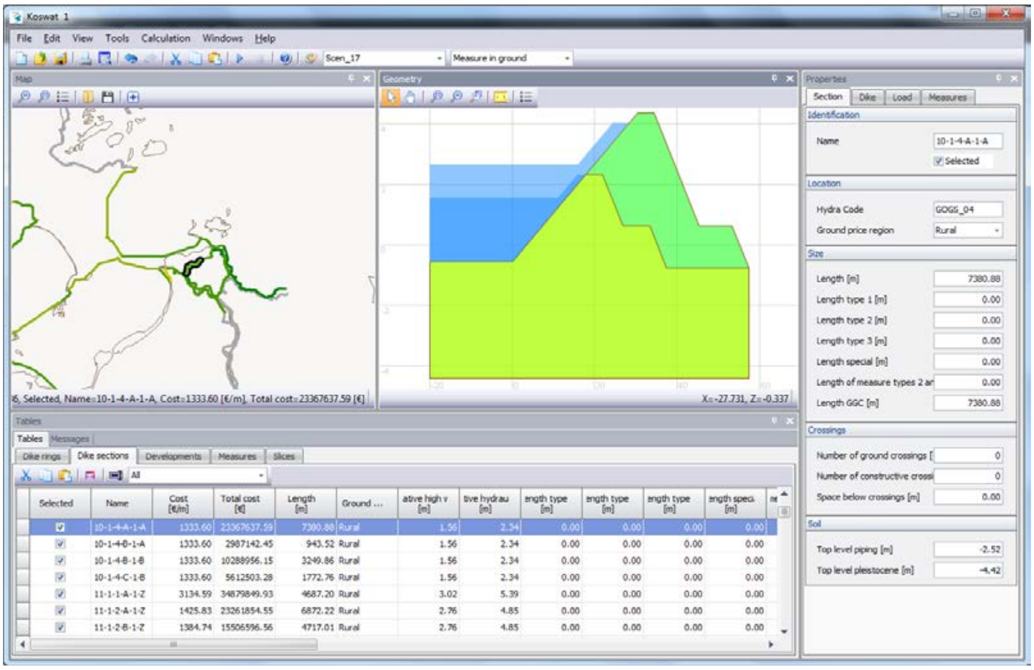


Figure 5.4 Example of an User Interface based on Delta Shell Light

The following generic features are provided as part of the different Delta-Shell Light components.

Feature	*Description*
Multi language support	The application can be displayed in multiple languages
Multi unit support	The application can be displayed with different units. In this way the user can select units appropriate to the size of values or what he is familiar with.
Track changes	The application keeps track the original data source of data and whether it has been modified by the user.
Startup behaviour	The application can be configured what to do on startup, load a new project or load the last used project.
Selection behaviour	The selected object is synchronized among all windows. This helps the user to understand what is displayed in all windows. For example: the map window, cross section, property window and table section all display the same selection of a certain object.

Delta-Shell Light uses C# components of the DevExpress and DotSpatial libraries. These libraries contain many different components for editing, visualization, reporting and exporting. Delta-Shell Light uses these features to create applications with a standardized look-and-feel.

Toolkit	*Description*
DotSpatial components	Display a map; open shapefiles/grids/rasters and images in a map; render and reproject map data etc.
DevExpress components	Various UI components : navigation pane, editors, grids, tree lists, ribbon bars, reports and charts, printing and exporting in various formats (HTML, PDF, XLS, CSV) etc

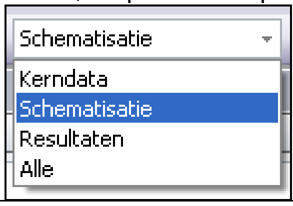
5.2.2 Menu and toolbar

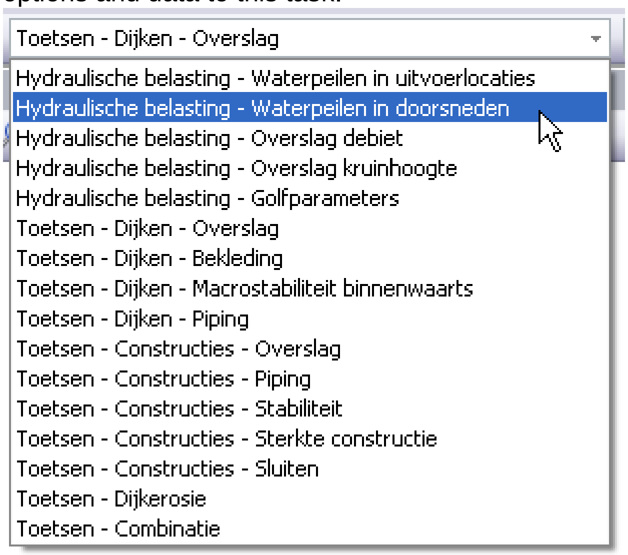
The main form will have a menu and toolbar. The menu will tentatively contain the following menu and submenu items:

Bestand/File	*Description*	*UC*
Nieuw/New	Creates a new Ringtoets project dabase	UC 5
Openen/Open	Selects an existing Ringtoets project database	UC 7
Project eigenschappen /Properties	(Re)defines the properties of the open project	UC 6
Opslaan/Save	Saves the current ringtoets project data or, if not saved before, performs save as behaviour	UC 8
Opslaan als/Save As	Opens a dialog asking where to save the Ringtoets project database	UC 8
MRU	List of most recently used projects	-
Importeren/Import	Import key-data (from GIS and soil database) using a preconfigured mapping table	UC 9
Importeren/Import	Import archived project data in XML format	UC 41, UC 44
Exporteren/Export	Archive project data in XML format	UC 41, UC 44
Afsluiten Project/Close	Closes the project	UC 48
Afsluiten Ringtoets/Exit	Terminates Ringtoets	UC 48

Bewerken/Edit	*Description*	*UC*
Ongedaan maken,Opnieuw /Undo/Redo	Undo and Redo recent actions	FR 26
Verwijderen/Remove		???

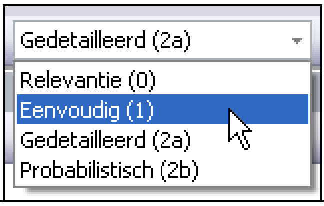
Beeld/View	*Description*	*UC*
Herstel/Restore	Restore the visibility of tabs to the initial settings	
Map/Kaart	Set focus to the map window	
Dwarsdoorsnede/Cross Section	Set focus to the cross section window	
Navigator/Navigator	Set focus to the navigator window	
Meldingen/Messages	Set focus to the Messages table	
Log uitvoer / Log output	Set focus to the Log output table	
Toon data / Show data	Select visible data	
• Alles / All	Show all available data	
• Kerndata / Key data	Show only key data	
• Schematisatie/Schematization	Show only schematized data	
• Resultaten/Results	Show only Results	
Tabellen/Tabels	Set focus to a selected table with input or results	
• Referentie lijnen / Dike Reference Lines	Input data for the dike reference line(s).	UC 10
• Karakteristieke lijnen / Characteristic lines	Input data for the characteristic lines, defining start foreland, toe outer berm, entrance point piping, outer toe, outer crest, inner crest, inner toe, toe inner berm, start ditch etc	UC 11
• Kunstwerken / Structures	Input data for structures like gates, concrete defence walls, and other water works	UC 12
• Dammen en Caissons / Breakwaters	Input data for breakwaters like caissons, rubble mounds and vertical walls	UC 13
• Bekleding / Revetment	Input data for different revetmentrevetment zones	UC 14
• Stijghoogtes / Piezometric head	Input data for the piezometric heads at land side on different horizontal locations along the dike location line	UC 15
• Dwars profielen / Cross section profiles	Input data for the cross section locations and surfaces, including links to output locations	UC 16
• Ondergrond / Subsoil	Input data for the subsoil profiles, soil types and parameters of soil types for different 1D or 2D subsoil profiles in different areas (bodemvakken)	UC 17
• Uitvoer locaties / Output locations	The available output locations of the hydraulic loading, with the input option to define fetch areas.	
……		

Werkproces / Work process	*Description*	*UC*
Work process	Select work process to limit the amount of visible tables, Map data and property data.  	
Kerndata / Key data	View and modify key-data	UC 10 ~ UC 17
Schematisatie / Schematize	Schematize mechanism related data	
	Link cross sections to output locations	UC 20
	Link cross sections to rouble mounds	UC 13
	Define fetch areas at the output locations	UC 22
	View/edit auxiliary parameters and settings	UC 23
Resultaten / Results	View results	UC 31, UC 36, UC 43
Alle / All	View all.	

Toetsen/Assess	*Description*	*UC*
Toetstaak / Task	Select an assessment task, in order to limit the visible options and data to this task.  	UC 19, UC 28
Hydraulische belasting / Hydraulic load	There are five tasks related to hydraulic load.	

• Waterpeilen in uitvoerlocaties / water level at output locations	Calculate water level data per output location.	UC 25
• Waterpeilen in doorsneden / Water level at cross sections.	Calculate water level data per cross section.	UC 25
• Overslag debiet / Overtopping / Overtopping discharge.	Calculate overtopping discharge per cross section given a required frequency and (existing) crest height.	UC 27
• Overtopping kruinhoogte / Overtopping crest level.	Calculate required crest height per cross section given the maximum allowed discharge for a given frequency.	UC 27
• Golfparameters / Wave parameters.	Calculate wave parameters per cross section, for a revetment assessment on level 1 or 2a	UC 26
Toetsen / Assessment	There are assessments per failure mechanism and for dikes and structures.	
• Dijken – Overslag / Dike – Overtopping.	Calculate results per overtopping dike section for a level 2a or 2b analysis	UC 27
• Dijken – Bekleding / Dike – Revetment.	Assess the cross section surface for overtopping and revetment. Schematize for revetment (stone, asphalt or grass), and calculate results per cross section for a level 1 analysis, or per macro-stability dike section for a level 2a or 2b analysis	UC 24
• Dijken – Macrostabiliteit binnenwaarts / Dike – macro stability inner slope.	Schematize for macro-stability, and calculate results per cross section for a level 1 analysis, or per dike section for a level 2a or 2b analysis	
• Dijken – Piping / Dike - Piping	Schematize and calculate piping results per cross section for a level 1 analysis, or per piping dike section for a level 2a or 2b analysis	
• Constructies – Overslag / Structures – Overtopping.	Schematize for overtopping of structures, and calculate results per structure. Calculate results per structure for a level 2b analysis	UC 27
• Constructies - Piping / Structures – Piping	Schematize and calculate piping results per structure for a level 1 or 2a analysis	
• Constructies - Stabiliteit / Structures - Stability	Schematize for structures, and calculate results per structure for a level 1, 2a or 2b analysis	

• Constructies – constructie sterkte / Structures – Structural Strength	Schematize for structures, and calculate results per structure for a level 1, 2a or 2b analysis	
• Constructies - Niet-sluiten / Structures - Nonclosure	Calculate results for non-closure of structures for a level 1, 2a or 2b analysis	
• Duinerosie / Dune erosion	Schematize for dune erosion, and calculate results per cross section for a level 1 analysis, or per dike section for a level 2a or 2b analysis	
• Combinatie/ Combine	Combine the results on cross sections (level 1), combination sections (level 2a) or presentation sections (level 2b)	UC 44

Toetsniveau / Assessment level	*Description*	*UC*
Assessment level	Select assessment level from pull down menu.  	
Relevantie (0) / Relevance (0)	Assess the relevance of a failure mechanism based on dike geometry, dike location and expert judgment.	CNS 6
Eenvoudig (1) / Simple (1)	Execute assessment on level 1 for selected mechanisms	UC 31
	Inspect results for all selected mechanisms on level 1 (for cross sections)	
Gedetailleerd (2a) / Detailled (2a)	Execute assessment on level 2a	UC 36
	Inspect results for different mechanisms on level 2a for mechanisms sections	
	Inspect results for different mechanisms on level 2a for combination sections	
Probabilistisch (2b) / Probabilistic (2b)	Execute assessment on level 2b	UC 42
	Inspect level 2b results on different mechanisms sections	UC 43
	Inspect level 2b results on presentation sections	

Gereedschap / Tools	*Description*	*UC*
Opties / Options	Define various options in an option window.	
Eenheden / Units	Define units for input and output of various properties	
Instellingen / Settions	Gives information on the Ringtoets version etc.	

Help	*Description*	*UC*
Handleiding / Manual	Gives access to the users manual (in pdf)	
Over / About	Gives information on the Ringtoets version etc.	

5.3 Data model

Before starting the technical design related to different functions, this section will first provide a description of the datamodel that is underneath in the different packages. The reason for using this sequence is that the technical design of functions will refer back to the datamodel. The datamodel itself will implicitely need to cover all the data.

5.3.1 Key data

The key data class contains the imported or inputted key data.

The following sections are present in the model for key data:

1. Sub soil data
2. Water defence data

5.3.1.1 Key data Sub soil

The soil database contains extended soil data including soil profiles and soil properties. The data is stored in 3D-spatial databases. In top view the available soil data are point objects. Advance GIS-tools can calculate a soil profile at any location in the area. In Ringtoets soil profiles at dike cross sections are necessary as input for failure mechanisms, for example stability and piping. The soil profile is either 1D or 2D. In a 2D profile, the boundary between two layers can vary along the horizontal cross section axis (perpendicular to the dike line).

The subsoil profiles will either be stored at mechanism sections or at regions. A choise between the two options must still be made.

The soil profiles are mechanism dependend. For piping a 1D profile is required, for other mechanisms a 2D profile is needed. Technically, 1D and 2D profiles are stored separately. For visualization routines are designed for 2D profiles. Conversion routines translate 1D profiles to ‘2D’ profiles when profiles are visualised. The presentation of 1D and 2D profiles will be different.

Figure 5.5 Data Classes for subsoil key data

The classes have the following meaning:

Class	*Description*
SoilProfile	The sub soil library contains a large number of 1D or 2D soil profiles. The locations of the imported profiles will be visible in the map meter as a symbol and a name (ID) label. Ringtoets will automatically link each dike cross section to the *nearest* soil profile. A tiny (dotted) line can make this link visible in the map meter. It is possible to change the links manually. In the cross section editor, the sub soil data will be visible as soil layers under the dike. By default the dike material is equal to the top layer

Class	*Description*
	material.
DeterministicSoilProfile	Soil profile which defines the appearance of a soil in a deterministic way, this means it is exactly defined which soil is present at which location.
StochasticSoilProfile	Collection of deterministic soil profiles, with each soil profile having a certain probability
SoilProfile1D	Describes a sub soil divided in horizontal layers
SoilLayer1D	Horizontal layer of a soil, with indication of top and bottom level resulting in layer thickness and layer position. The bottom level is always equal to the top level of the underlying soil layer. Piping indication (upper subsoil layer, shallow aquifer at dike, shallow aquifer next to dike, second deep aquifer). NL: naam, ligging bovenkant (laagdikten), type voor piping (deklaag, ondiepe watervoerende laag onder de dijk, ondiepe watervoerende laag buiten de dijk, tweede diepe watervoerende laag), ligging, laagdikte.
Soil	Contains all soil properties, such as mass density (dry and wet), piping parameters, damping factor, is aquifer or aquitard and stability parameters. NL: soortelijke dichtheid, parameters voor pipingmodel, bijv. erosiebestendigheid toplaag, weerstandscoëfficiënt onderlaag (afhankelijk van ligging). Stabiliteits parameters.
SoilProfile2D	Describes a sub soil, where the appearance of the soil depends on the horizontal coordinate
SoilLayer2D	Describes a 2D layer, i.e. the thickness and position of the soil depends on the horizontal coordinate. One can think of a polygon indicating the position of the soil. Piping indication (upper subsoil layer, shallow aquifer at dike, shallow aquifer next to dike, second deep aquifer). NL: naam,
SoilSurfaceProfile	Soil profile which consists of a deterministic soil profile and a surface line. The surface line truncates the soil profile from the air.
SurfaceLine	The surface line is a collection of points on the surface in such a way that it describes the contour of the dike. Usually the points are collected from DTM and corrected for riverbed and ditch. The points are supposed to be perpendicular to the dike line. The surface line has a surface line location, which is a point in RD coordinates, and an angle, which indicates the angle of the line with surface points with the RD latitude. The points are defined with relative coordinates to the surface line location and angle (X is distance to surface location, Y is zero, Z is real depth)
SchematizedSurfaceLine	A surface line which is based on a surface line, but modified in such a way that it can be used by a failure model. This includes the definition of a number of characteristic points and possibly some additional bending points on the surface.
CharacteristicPoint	Characteristic lines run parallel to the dike line and are imported as key-data. In the cross section editor the lines are visible as characteristic points at intersections with the surface line. The user can select, move, add and delete these characteristic points. Adding and moving is only possible *along the surface line*. Characteristic points must be labeled as: begin point fore land, entrance point piping, toe outer slope, outer crest, crest, inner crest, inner slope, toe inner slope, start ditch, end ditch, etc. NL: karakteristieke punte op dijkprofiel: begin voorland, intreepunt

Class	*Description*
	(piping), teen buitenberm, buitenteen, buitenkruin, kruin, binnenkruin, binnenteen, teen binnenberm, start sloot, eind sloot, enz.
GeometryPoint	3D Point, which indicates a point in a surface line. The X and Y coordinates indicate the geographic location, but defined relatively to the location of the surface line.
Stochast	Defines the stochastic distribution of a property in, for example, soil. The distribution type and parameters define the stochastic values. The number of values depend on the distribution type. The following distribution types exist: Deterministic (1 value), Normal (2), LogNormal (3), Uniform (2) For each stochastic parameter there is an associated property in a class, for example DryUnitWeight stochastic parameter is associated with the DryUnitWeight base property (being a double) in the soil class. This is defined by the owner and property in this class.

5.3.1.2 Key data water defence

This comprise all key data related to the water defence geometry and properties.

Figure 5.6 Data Classes for hydraulic key data and boundary conditions

The classes have the following meaning:

Class	*Description*
DeltaModel	Container of all key data, such as soil profiles, dike lines and revetment location and properties
DikeLine	A dike line is a ‘backbone’ of a dike and applicable for all failure mechanisms. The user can select points along the dike line to view properties such as a name. Points have global XYZ-coordinates and local L-coordinates along dike line. Locations can have name (labels) or L-coordinate indications (km-pole) NL: naam locatie, km-palen
CharacteristicLine	Line of points of the same characteristic type. These points are used to derive the characteristic points per schematized

Class	*Description*
	surface line. The Characterstic points are the intersections of characterstic lines with SurfaceLines.
Fetch (*)	Fetch area. The incoming angle is relative to the dike normal (perpendicular to dike line)
WindFetch (*)	Fetch data per wind direction
FetchLength (*)	Fetch data per wind direction and layer
Revetment	Revetment zones are visible in the map editor and cross section editor. Revetment zones are defined by two paths in the horizontal plane, indicating the left and right border of the revetment zone. The distance is related to crest axis. Such a path is expected to be close to the dike line, but not necessariliy so. A path is a line consisiting of points. The actual top and bottom at a certain location become clear in combination with a (schematized) surface line (intersections revetement paths with surface line). The user can select, add, edit and remove revetment zones. Revetment types: grass, stone, asphalt, with sub-types. Revetment has physical revetment properties such as size and parameters for mechanism models. The model parameters are different per revetment type and sub-type. Inpuft for each property the mean value, statistical standard deviation and standard deviation used for mechanism. There can be more than one revetment zones in one cross section (profile sections or revetment zone sections on the surface line). NL: Bekledingszone, zonenaam, bekledingstype (gras, steen, asfalt met onderverdelingen), onder en bovengrens zone, bekledingseigenschappen (afmetingen, faalmechanisme specifieke parameters).
Structure	Hydraulic Structures like gates, concrete defense walls, etc Structurs are line objects and have a begin and endpoint (location points). Their line symbology in the map is different from the dike. They have a name, type, geometry, and other assessmemt specific properties. NL: kunstwerk; verticale muren. Eigenschappen: naam, type, afmetingen, overige eigenschappen voor toetsing.
Breakwater	Breakwaters like dam caisson, rubble mound, are line objects. They have a begin and end point (location points). The structures have a symbology that is different from the dike line. (e.g. line width, colour) in the map editor. The user can select a the structure and open its project property form for: name, type, geometry and other assessment specific properties. NL: dam, caisson, strekdam. NL: eigenschappen: naam, type, afmetingen, overige eigenschappen voor toetsing.
PiezometricHead	Piezometric Head is imported with key-data in the map editor as polygons. It is applied to all cross sections inside a particular polygon. Cross sections outside the polygon will need additional, manual input of the Piezometric head in the cross section editor.

Class	*Description*
PolderLevel	Water level at the polder side, to be used as water level in a ditch on the polder side. NL: polderpeil.
WaterLevelSetup (*)	User defined water level setup value per wind direction. NL: opzethoogte, windrichtingsector.
Swell (*)	Wave parameters due to swell, no user data. NL: deining, golfhoogte, golfperiode.
WaterLevel	Water level at dike toe at the river side (if available).
Wave (*)	Wave data at dike toe. Properties are peak period and angle, i.e. angle of attack onto dike
Seiche (*)	Defines a seiche, i.e. a long standing wave

(*) should not be part of project data, but part of internal database.

Default values for hydraulic parametes will be applied if available.

5.3.1.3 *Linking routines key data*

Key data is translated to object classes. The relations between object classes are defined in class diagrams, which can be found in the following secions of this chapter. The class diagrams tell us what data is linked but not how the links are created. This section elaborates the basic design principles for linking object classes geographically. The purpose of these design principles is to guarantee correct and validated links of object classes. The principles will be used to design the linking routines (methods). The exact moment of activating linking routines is important for the performance of the UI. Timely activating also guarantees that the most recent data is used.

Design princples for linking routines of key-data

- The dike line is the ‘backbone’ of the model. Every linking routine must check on the availability of it. If a dike line does not exist, the linking routine must be aborted. Furthermore, if there is any change or modification to the dike line, all linking routines must be updated.
- All data is projected on the dike line. A point on the dike line is called *location point*. Generic projection methods are necessary for the projection of different types of data on the dike line using a *perpenducular*. A *point object*, for example a hydraulic boundary point, must be projected on the closest dike location using the perpendicular. On that particular spot a location point is inserted on the dike line and linked to the hydraulic boundary point. The projection of a *line* on the dike line is somewhat different. Both the begin and end point of the line must be projected on the dike line. A *polygon* is another data type. Its boundary can cross the dike line twice. The dike line between these two intersections (location points) lies inside the polygon.
- Soil data are imported in soil segments being areas (polygons) with a set of 1D or 2D soil profiles. Each profile has a probability of occurance.
- Every location point on the dike line has a XYZ-coordinate in the global coordinate system and *dike line coordinate* (L-coordinate).
- The connecting algorithms use *spatial imaging* technique to optimize the search algorithm.
- After the data has been projected on the dike line, it can be projected on the cross sections including the dike surface lines.

- In Ringtoets, importing, editing and manually adding key-data is possible. All of these actions can affect the data and the associated data links. To guarantee that the most recent and actual data is used for calculations and visualization, the linking routines must be called only when it is necessary. This is the case if any object data has been added, deleted or moved and at the same time:
  a) a dike cross sections is open(ed), or
  b) a calculation routine is called.

The following tables is a list of key-data, the linking routine, and the associated object class.

Data item (shape type)	*Linking routine*	*Class*
Start		
Background (picture)	N.a.	
Dike line (‘Backbone’)		
Dike line (line)	Dike points are added to list of dike locations. Existiance of a Dike line is prerequest for any linking routine.	DikeLine, DikeLocation
Hydraulic structure (line)	Begin- and end point projected on dike line.	Structure DikeLocation
Dike cross section		
Surface lines (line)	Surface line has a location point. Link location point to dike line. Surface line has angle relative to dike line orientation (perpendicular).	SurfaceLine, DikeLocation
Cross section (point)	Cross section is a location point on dike line. In cross section the dike geometry, soil data and hydraulic boundaries are combined.	DikeLocation, DikeCrossSection
Characteristic lines (lines)	Intersect characteristic lines with surface lines. Create characteristic points.	CharacteristicLn, CharacteristicPnt, GeometryPoints, SurfaceLine
Revetment zone (polygons)	Intersect zones with surface lines. Create dike surface points.	Revetment, GeometryPoints
Soil data		
Soil profiles from DSoilBase (polygons)	Import *SoilSegments* with soilprofiles per segment, including probability. Segements have either 1D or 2D profiles. Project soil segment (polygon) on dike line. Assign cross sections to SoilSegments (thus soil profiles).	SoilProfile1D/2D, DikeLocation, *DikeSegments,* DikeCrossSection
Dike material (point).	Assign top soil layer to dike profile as dike material.	SoilLayer1D, SoilLayer2D, Soil, DikeCrossSection
Boundary Conditions		
Piezometric head	Project polygon on dike line.	DikeLocation,

Data item (shape type)	*Linking routine*	*Class*
(polygon)	Apply to nearby cross section.	PiezometricHead, DikeCrossSection
Polder level (polygon)	Project polygon on dike line. Apply to nearby cross sections.	DikeLocation, PolderLevel, DikeCrossSection
Breakwater (line)	Project breakwater on dike line. Mark begin and endpoint as dike locations. Link breakwater to affected cross sections.	Breakwater, DikeLocation, DikeCrossSection

5.3.1.4 Partial safety factors

Partial safety factors are necessary for the semi-probabilistic assessment (level 2a). The partial factors will only be applied to strength parameters (resistance) and not to the load parameter. In theory, it is possible to apply partial safety factors either on the overall calculated strength of a mechanism, or on the individual strength parameters such as material properties. There will be a switch per failure mechanism to distinguish between an overall partial safety factor or partial safety factors per strength parameter.

The above mentioned switch and all partial safety factors are part of configuration data. This means that the user can inspect the factors in the userinteface per mechanism (UC 35), but cannot modify them.

If the switch is set to ‘overall’, the strength parameters accepts only μ and σ as input and have a *characteristic values* as output. If the switch is set to ‘parameters’, the individual strength parameters accept μ, σ and γ_i as input. The output is the *design value*.

5.3.2 Assessment model (schematized data and results)

5.3.2.1 Schematized data

Dike lines are subdivided for a level 2 assessment into dike sections (mechanism sections, combination sections and presentation sections). A mechanism section relates key data and additional hydraulic boundary data via the location of a characteristic cross section inside the mechanism section.

Figure 5.7 Data Classes for Dike location.

The classes have the following meaning:

Class	*Description*
DikeLineDivision	Definition of a division of dike into sections. Note that soil model doesn't refer to this class. It will be used by the assessment model. NL: vakindeling dijklijn, mechanisme vakken.
DikeLocation	Location or stretch along a dike
DikeCrossSection	Cross section which is used at level 0 and 1. The location coincides with a schematized surface line. Cross sections have (default) names.
DikeSection	Dike section which is defined as a stretch along a dike and using the key and hydraulic boundary data from a

Class	*Description*
	representive DikeCrossSection

Since dike sections refer to hydraulic data, which are considered representive for the dike section, sometimes combined hydraulic boundary conditions are used. They are modeled as follows:

Figure 5.8 Data Classes for Hydraulic Boundary parameters.

Class	*Description*
CombinedSwell	Has swell properties, which are the result of a weighted combination of underlying swells
CombinedWaterLevelSetup	Similar as combined swell
CombinedFetch	Similar as combined swell

5.3.2.2 Assessment control model

The assessment model contains data needed by assessments and the failure mechanisms they use. The assessment model will refer to key data. Soil profiles are essential input data for a dike cross section. The collection of soil data for the assessment also depends on the failure mechanism and the failure mechanism section division (DikeLineDivision / MechanismDikeSection). Some additional soil parameters are mechanism specific, for example the damping factor for the failure mechanism piping.

Figure 5.9 Classes for Assessment control

Figure 5.10 Classes for probabilistic configuration

The classes have the following meaning:

Class	*Description*
AssessmentModel	Gives access to all data needed for an assessment
AssessmentMechanism	Calculates the limit state value for
AssessmentNeeded	Indicates whether assessment is needed per assessment level, failure mechanism and dike section
DikeLocation	Location or stretch along a dike, either a DikeCrossSection or a DikeSection
DikeLineDivision	Defines a division of a dike line into dike locations or dike stretches. Per failure mechanism a dike line division exists, but also for combined and presentation sections and for cross sections for assessment level 0 and 1. The dike line division contains a list of division points. This is a list of IGeograpics which define the limits of the dike sections. The same IGoegrapic instances are present in the dike sections.
Mechanism	A failure mechanism calculation
MechanismDikeSection	A dike section defined for a certain mechanism.
OvertoppingDikeSection	A dike section defined for overtopping. An overtopping dike section is linked to a (user defined) mechanism section (via DikeLineDivision, DikeLocations, MechanismDikeSection). The mechanism section is

Class	*Description*
	linked to a schematized surface line and cross section (via a DikeLocation). The cross sections is linked to geometric data, soil data and hydrodynamic data. This schematized surface line is called 'charcteristic cross section' (UC34.d). List of non-default values for allowable overtopping discharge. NL: non-default waarde voor toelaatbaar overslagdebiet.
OvertoppingMechanism	Performs an overtopping calculation for one dike section. List of allowable overtopping discharge. NL: toelaatbare overslagdebieten.
PipingDikeSection	A dike section defined for piping. See comments on mechanism sections at 'OvertoppingDikeSection'. Characteristic cross section can also link to probabilistic soil profile. Default piping model. Optional: non-default damping factor (user defined). For piping two additional points must be added: 1) Entrance point using support lines or toe outer slope (conservative assumption). 2) Excess point using determined by algorithm or inner toe (conservative assumption). NL: intreepunt, uittreepunt, binnenteen, buitenteen.
PipingMechanism	Performs a piping calculation for one dike section Default value damping factor hydraulic pressure difference between entrance point and inner crest toe. NL: dempingsfactor stijghoogte (tussen intredepunt en binnenteen).
RevetmentDikeSection	A dike section defined for revetment. See comments on mechanism sections at 'OvertoppingDikeSection'. Per mechanism type and sub-type non default model parameters.
RevetmentMechanism	Performs a revetment calculation for one dike section. Default model parameters per mechanism type and sub-type.

5.3.3 Import and export

This section contains classes for facilitating import. Export is handled by DeltaShellLight components. The classes are described together with their interaction in section 5.5.

5.3.4 Failure mechanisms

The failure mechanisms package contains classes to calculate a failure mechanism. Its input and output data are part of key data, except calculation options.

5.3.5 UI

Two UI packages contain the forms specific for items in the *key data* and *assessment model* classes. The naming of these classes is <item>PropertyControl, so the form where the user can enter swell data is called SwellPropertyControl.

For drawing items in the cross section editor, there will be specific classes per item (as far as needed), called Drawing<item>. For example, the class DrawingRevetment draws the revetment zones in the cross section editor.

Other kind of UI controls don't need a specific class, because DeltaShellLight provides sufficient components already, for tables, charts and display of data in GIS.

5.3.6 Ringtoets plugin

The Ringtoets plugin has some control classes which configure and control Ringtoets. This comprises the registration of property controls for certain item types, the configuration how data should be displayed in GIS and the behaviour of the GIS and cross section editor.

These classes are mentioned in the description how these editors behave, see sections 5.6.2 and 5.6.3.

5.4 Project management

5.4.1 Start a new project

At the start of a new project, input of project settings is necessary, like the project database name and location. Ringtoets will come up with one Project Start Form that holds all those items together. The form pops up directly after selecting 'Create new project'. The form also pops up if one of the items in the Project Start Form is missing of an existing project. After the users confirms these data, the data are imported and saved immediately. If the project exists already, the user is prompted to overwrite.

When starting the application, the user is prompted with a form to create a new project or to open a previous project. This form is merged with the previous form.

See UC 5, UC 6 and UC 7.

5.4.2 Automatic Locking of data

The Ringtoets application allows concurrent use of one project database. But users are not allowed to edit the same data at the same time, or to alter data which is in use for a running assessment calculation, see UC 18. Therefore locks are used: A user requests a lock for a certain part of the data and if granted, he is allowed to edit it. If refused, he can still view the data, but isn't allowed to modify them.

Locking is performed implicitly on a first come, first served basis. Users do not have to identify themselves. Locks can be set on key data and on failure mechanisms. The following table indicates the required locks per action.

Action	*Lock*
View data	None
Edit data	Changed but unsaved data
Calculate hydraulic boundary conditions	All used data
Perform level 1 assessment	All used data
Perform level 2a assessment	All used data
Perform level 2b assessment	All used data

Figure 5.11 Activity diagram for mechanism dependent locking

The locker class sets a semaphore for the selected lock type. This semaphore is a file, which is opened exclusively. Only when this open action succeeds, the lock is granted. It doesn't matter whether the file existed already, because this prevents the whole system being locked up if an application terminates unexpectedly.

5.4.3 Saving data and configuration

All Ringtoets project data is saved in a project database. Import and export of project data occurs via a separate xml file for the key data and general project data and separate xml files for data related to the the different mechanism branches for level2 assessment. In this way, concurrent data updates for different mechanism branches are possible.

Figure 5.12 Data Classes for writing to the project database

The classes which are not accessible by the RingtoetsProject are used to control and configure the user interface. The RingtoetsPlugin makes the connection with the Delta Shell Light framework.

5.5 Import and Export

5.5.1 Import and export data model

Importing data is performed from several file formats. As long as a file format targets one data type of object, this is done in a generic way. The file format is described by attributes or in an xml file. Then the data is read and corresponding data classes are populated. The soil model is queried for providing appropriate data classes. This is visualized in the figure below:

Figure 5.13 Activity diagram for importing data

This is implemented in the following classes:

Figure 5.14 Data classes for importing data

The classes have the following meaning

Class	*Meaning*	*UC*
Importer	Takes care of populating data classes based on data read from file	
ShapeImporter	Imports data from shape file	
CSVImporter	Imports data from CSV files	
MultiImporter	Starts import from several data sources and runs them in parallel.	
FieldDefinition	Collects property definitions for one class type	
PropertyDefinition	Defines the relation between a field name (e.g. the header in a CSV file) and a property in a data class	
FieldDefinitionImporter	Fills the field definition	
AttributeFieldDefinitionImporter	Fills the field definition based on attributes defined in the data classes	
XMLFieldDefinitionImporter	Fills the field definition based on an xml definition	
IDataFactory	Interface which defines a data factory, i.e. a data source which is capable to provide an instance of a data class based on a type definition. The	

<table>
<tr><th>Class</th><th>Meaning</th><th>UC</th></tr>
<tr><td></td><td>following methods are provided:

<table><tr><th>Method</th><th>Description</th></tr><tr><td>GetObject</td><td>Retrieves or creates an object of the requested type and key and locates it in the proper place, e.g. a swell is added to the list of swells.</td></tr></table></td><td></td></tr>
<tr><td>DeltaModelFactory</td><td>Implementation of the IDataFactory for the delta model</td><td></td></tr>
<tr><td>DeltaModel</td><td>Top object of the delta model, see elsewhere.</td><td></td></tr>
</table>

5.5.2 Import user interface

When the user wants to import data, a form is displayed in which he can select per data type whether it should be imported and if so, its file location. Pressing the OK button will start the import.

Next to the OK and Cancel button, there is the possibility to save and load file locations from an import definition file.

5.5.3 Format of imported and exported data

Imported data and exported has either a csv, shp or xml format. Different types of data can be contained in different files.

5.6 Editing data

5.6.1 Modification of key-data

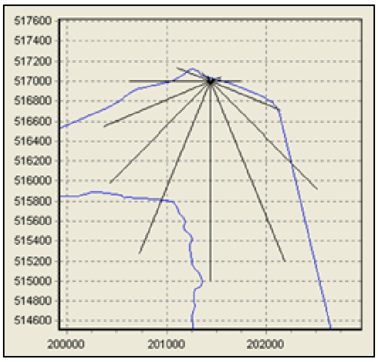
The UI of Ringtoets will use Delta Shell Light components (§ 5.2.1) such as a map and cross section window. Other UI components are property editors and tables. The user can select and modify objects through one of these components. The content of all these UI components is synchronized. With synchronization the property editor is for example updated if a user selects a new object in the map-editor. Some key-data is mechanism specific. The user must select the assessment level and mechanism with the Map Editor *controls,* for the purpose of data filtering. Initially, the key-data is used for all mechanisms. When editing the key-data for one specific mechanism, Ringtoets implicitly will make a duplicate (copy) which can be altered per mechanism.

Key-data is imported from external source and saved to the I project database. It is a ‘snap-shot’ of the external data. Modifications on the project data will *not* be stored (or otherwise synchronized) in the original data source.

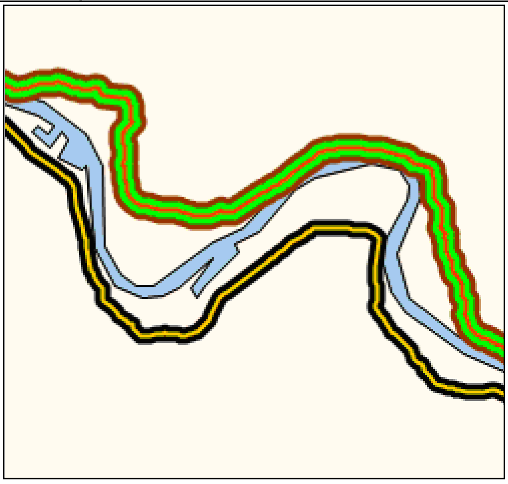
General User Interface functionalities are described § 5.2, together with the access to specific menu functions for modification and visualization of key-data.

5.6.2 Map window

This section describes the functionality of the map window in detail. The Map window shows the dike geometry in top view, so only georeferenced data is visible. Data can be selected and then their properties are displayed in the property form. The following items are visible on the map.

<table>
<tr><th>Item</th><th>Description</th><th>UC</th></tr>
<tr><td>Layer</td><td><table>
<tr><td>Background picture (local or from server)</td><td>Achtergrondkaarten</td></tr>
<tr><td>Geographic coordinate system</td><td>Coördinaat definities</td></tr>
<tr><td>Layer definitions (optional)</td><td>Laag definities</td></tr>
</table></td><td></td></tr>
<tr><td>Dike line</td><td>A line with bending points, which indicates the location of the dike</td><td>UC 10</td></tr>
<tr><td>Soil segment</td><td>Dike stretch representing the location of a soil segment</td><td></td></tr>
<tr><td>Structure</td><td>Dike stretch representing the location and type of a structure</td><td></td></tr>
<tr><td>Breakwater</td><td>The location of a breakwater</td><td>UC 13,
UC 21</td></tr>
<tr><td>Fetch</td><td>Group of lines pointing towards wind directions, see examples from Hydra-VIJ and PC-Ring below.



Import of precalculated fetch tables.
Automatically calculate fetch lengths (nice-to-have).</td><td>UC 22</td></tr>
<tr><td>Swell</td><td>Symbol representing the location of swell input</td><td></td></tr>
<tr><td>Revetment</td><td>Indicates the revetment zones along a dike. Per revetment zone there is a line, so there may be multiple lines together, see the example below.</td><td></td></tr>
</table>

Item	*Description*	*UC*
	 *Figure 5.15 Revetment zones in Map Editor for dike with three revetment layers (upper line) and two revetment layers (bottom line)*	
Dike section	A dike section (mechanism section, presentation section) is indicated by small dike section points, indicating the begin and end of the dike section. Editing dike sections comes down to adding, moving or deleting dike section points.	

Coloring dike sections and dike lines can be done in the following ways. The user can select this with a drop down list in the toolbar of the map editor.

Draw mode	*Display*
Input	Input values for the selected failure mechanism, such as revetment.
Assessment level	The needed assessment level and whether it fails or passes
Section failure probability	The failure probability per dike section. This depends on the selected failure mechanism or combined or presentation sections
Dike line failure probability	Same as section failure probability, but for the whole dike line

Labels appear with appropriate information about what is displayed.

5.6.2.1 General map operations

The user can perform the following general GIS actions

Action	*Description*
Zoom and pan	General GIS features, including mouse scroll functions.
Select item	Select an item with the mouse pointer. Its properties are shown in the property window at the right side of the screen.
Move point	Move selected cross section *along* the dike line (optional)
Show / hide layers	Each of the items listed in the table before appears in a layer. This layer can be hidden or made visible.
Display layer information	Colors and symbols and their meaning can be displayed and edited in a legend.

Action	*Description*
Save layer	Each layer (except a WMS layer) can be saved to a shape file
Add / remove background layers	Background layers can be loaded from shapefile or retrieved via a WMS server (e.g. OpenStreetMap). They can be removed as well.
Reorder layers	The layers can be reordered with the following limitations • The WMS layer is the bottom layer always • A polygon layer is always behind a point or line layer
Display fetch area	Show fetch areas per cross section. Each fetch area points towards a wind direction.

5.6.2.2 Linking Output Points to Cross Sections

Cross sections are points on the dike line that contain dike geometry and soil data. Additional data from the Hydrodynamic Database is also required in the dike profile. Hydrodynamic data is located in geographic *output points*. A link between a cross section and a hydrodynamic output point is necessary. Because there are typically many cross sections, and *automated linking* routine is necessary (UC 20).

It will be assumed here that hydraulic structures are also linked to a representive cross section plane.

With the ‘Link’ button on the form, the user can start the automated linking routine. Ringtoets will pop up a warning message that says that any existing link will be removed. After a final confirmation, Ringtoets will start the automated linking routine.

Ringtoets will look for a nearby output point for every single cross section point. For every point, Ringtoets looks for the closest output point within an inner threshold distance. If there is one (or more) points within the threshold distance, only the closest point is linked to that cross section. If none output point is found, the search area is enlarged to a larger, outer threshold distance. When there are two output points in that area, Ringtoets will couple both output points to that cross section (Figure 5.16). The database parameters are calculated by interpolating the values from both output points using the mutual distances to determine their relative influence. No link is made if one or zero output points are found inside the outer threshold.

The links between the cross sections to the output points are displayed. A thin, light colored line in the Map Editor visualizes the links. The cross sections without a link get a different, striking color (e.g. orange).

Manual linking of cross sections to one or two output locations is possible via the cross section list window or via the map, see UC 20. Removing links is possible as well.

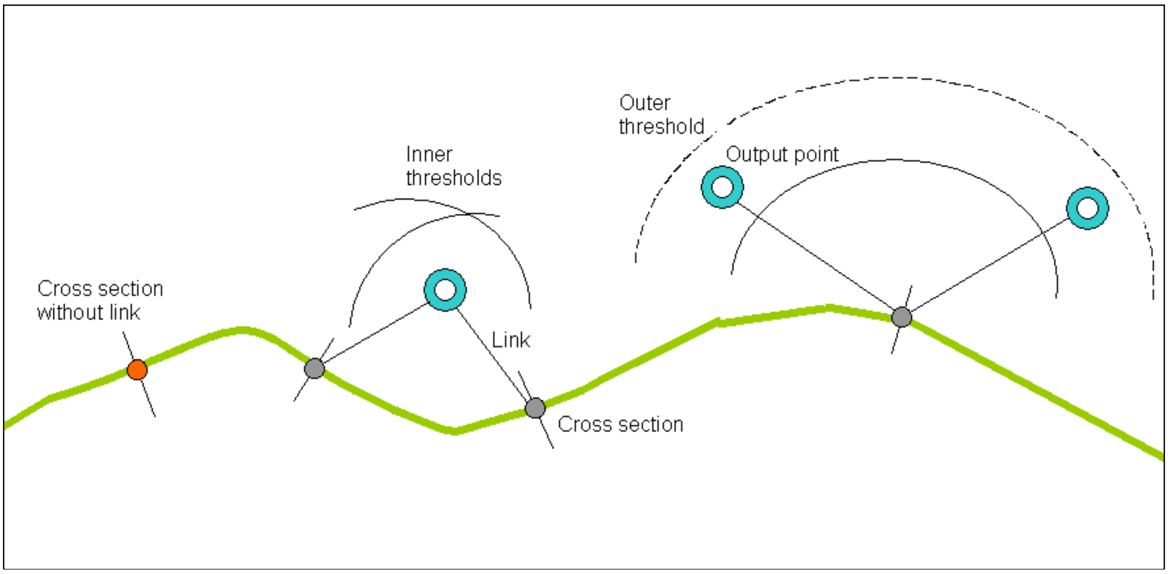


Figure 5.16 Automated linking of cross sections to output points of hydrodynamic database

Cross sections without a linked output point are allowed for level 1 assessment. In that situation, additional interpolation of the hydraulic boundaries from adjacent cross sections is necessary. For level 2a a linked output point is required to a characteristic cross section of every mechanism section.

5.6.2.3 Linking Breakwaters to Cross Sections

For linking breakwaters to cross sections, see UC 21

5.6.2.4 Editing dike sections

A level 2a or 2b assessment requires *dike sections* instead of cross sections. The two user-defined types of dike sections are ‘mechanism sections’ and ‘presentation sections’. The mechanism sections are homogenous dike stretches used as input for failure mechanisms. Presentation sections are dike stretches used for the combined failure probability of multiple mechanisms (level 2b).

Initially the entire dike line is one large section. The user can *split* a dike section in two parts by adding a *division point*. A division point is a point *in between* two adjacent cross sections. It is only possible to apply a division points at one of the available *dike points*. A dike point divides the dike line between two cross sections. As a consequence, the smallest dike section possible contains only one cross section. The mouse pointer automatically *snaps* to those dike points. It is for example possible to *move* a division point along the dike line and release it at one of the existing mid points. *Removing* a point is possible as well. For convenience, the adjacent dike sections get contrasting coloring (dark/light) for good visibility.

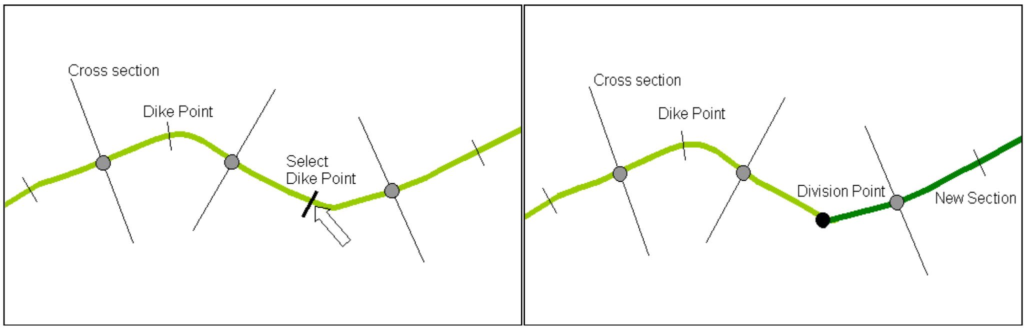


Figure 5.17 Splitting a dike section by adding a division point

The user can add or remove a dike point. Ringtoets automatically redraws the mechanisms sections.

Revetment zones (§ 4.5) and subsoil scenario's for piping and slope stability are expected to be defined already as key data along the dike line. A toolbar button 'Use Revetment Division' is enabled if the mechanism Revetment is selected in combination with a level 2 assessment. When clicking this button, the existing division points are removed and the revetment zone boundaries are imported as new division points. Manually adjustment is possible thereafter. The same procedure applies for using the subsoil scenarios division (button "Use Subsoil division") to determe a first division of mechanism sections for piping and slope stability.

If the length of a *mechanism section* becomes smaller than the minimum value, Ringtoets will give an error. The first proposed repair action is to remove the end-point of that small section and as a result merge it with the next mechanism section. If the end-point is the end-point of the dike line, than the begin point of the small section is removed.

During a level 2a assessment, Ringtoets will create *Combination sections* (for level 2a assessment) from the user input of mechanism sections. The division points of the mechanisms sections are projected on one dike line. Ringtoets uses combination sections to indicate the stretches for which all different level1 or level2a assessments pass the associated assessment criteria of the different mechanisms.

For level 2b the user can define *presentation sections* for the output. The begin and end-point of a presentation section must coincide with the division points of the combination sections. In a way, presentation sections are groups of combination sections. The location of the begin and end-points of presentation sections can therefore not be edited, since they must coincide with the begin and end-points of mechanisms sections.

Initially the presentation sections are a copy of the combination sections. The user can edit them by removing division points. As said before, adding division points is only possible at begin and end points of combinations sections.

Figure 5.18 Activity diagram for map based editing

Figure 5.19 Activity diagram for changing the dike location line

5.6.2.5 *Linking characteristic cross section to mechanism section*

Level 2 uses *mechanism sections* instead of cross sections. Mechanism sections are stretches of a flood defense with more or less homogeneous properties and boundary conditions for a considered failure mechanism. A mechanism section contains one or more adjacent cross sections. A mandatory prerequisite is that one cross section is indicated as the characteristic cross section of the mechanism section. Characteristic means that the cross section is characteristic for the entire mechanism section. The properties attached to the cross section location become the input for the considered failure mechanism.

In the Map Editor there is a button to activate the ‘Link characteristic cross section’ mode. In that mode the user can mark a cross section inside a mechanism section as the characteristic section. First the user selects a mechanism section on the dike line. Second the user selects a cross section. Manual input in a mechanism sections list is possible too. The characteristic cross section gets a more striking color or shape (Figure 5.20).

In the Map Editor toolbar there is also a button ‘Link to the most central cross section’. When pressing this button, a dialog appears in which the user must confirm that all existing characteristic cross sections for a certain mechanism branch will be removed. After confirmation, Ringtoets will remove all existing indications of characteristic cross sections and then look for the cross section location which is most close to the center of the mechanism section. Manual adjustments thereafter are possible.

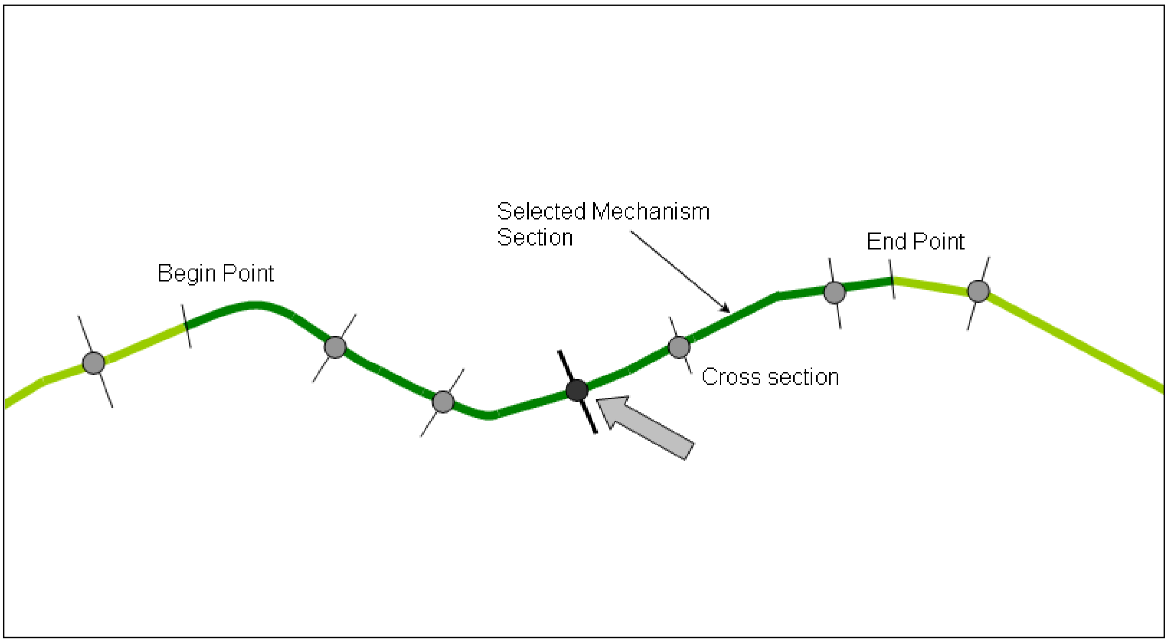


Figure 5.20 Manually select characteristic cross section for mechanism section.

5.6.3 Cross section editor

This section describes the functionality of the cross section editor in detail. The purpose of the cross section editor is to provide a comprehensive view of data defined at a dike section. The data will be visualized in the LZ plane. Only data which can be visualized in this plane will be displayed, for example sub soil data, a surface line, water level, etc., but not dike lines and computational settings.

The figure below schematically displays the cross section editor:

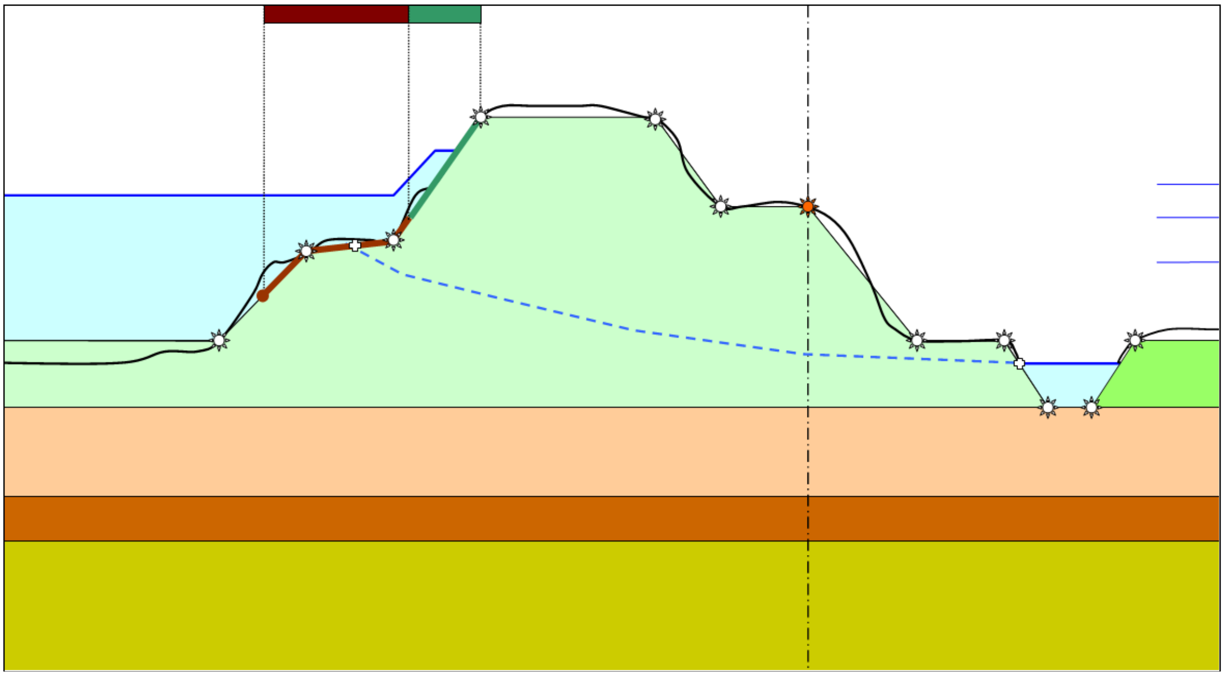


Figure 5.21 Modifying characteristic points along surface line in dike cross section editor

The following items are displayed:

Item	*Actions*	*UC*
Surface line	Selectable	21
SchematizedSurfaceLine	Points can be added, moved and deleted.	
Characteristic point	By default a characteristic point is located on the dike surface line. Its position is editable by dragging a vertical cursor line, which appears after selecting a characteristic point. The line can be dragged to the left or right, which leads to a repositioning of the characteristic point on the surface line. The point 'snaps' to dike points only (default). Characteristic lines determine the location of characteristic points on the surface line. After a modification of a characteristic point, the characteristic line will not be updated. This means that updates to charactersitc lines are not saved. In the map, the imported characterstic line is displayed. When selecting a characteristic point, the user can select 'Disconnect' option in the context menu (right mouse button). Disconnect is a point property. With this option, it is possible to drag the	21

Item	*Actions*	*UC*
	characteristic point to a position *free from the surface line*, see Figure 5.22. Of course, the validation rules for the schematized dike line still apply (§ 5.7). Those functions are only enabled for Overtopping and Stability.	
Piping entry and exit point	Selectable	21
Soil layer (1D and 2D)	A soil layer can be added or removed	21
Soil	Displayed in the soil layer	21
Piezometric head	Selectable for Piping and Stability.	18
Revetment	Selectable. A revetment zone has a start and end point in the cross section editor in *horizontal* direction (Figure 5.21). The user can select, add, edit and remove revetment zones. Overlapping zones are not allowed, gaps between zones are.	19
Swell	Selectable	
Water level setup	Selectable	

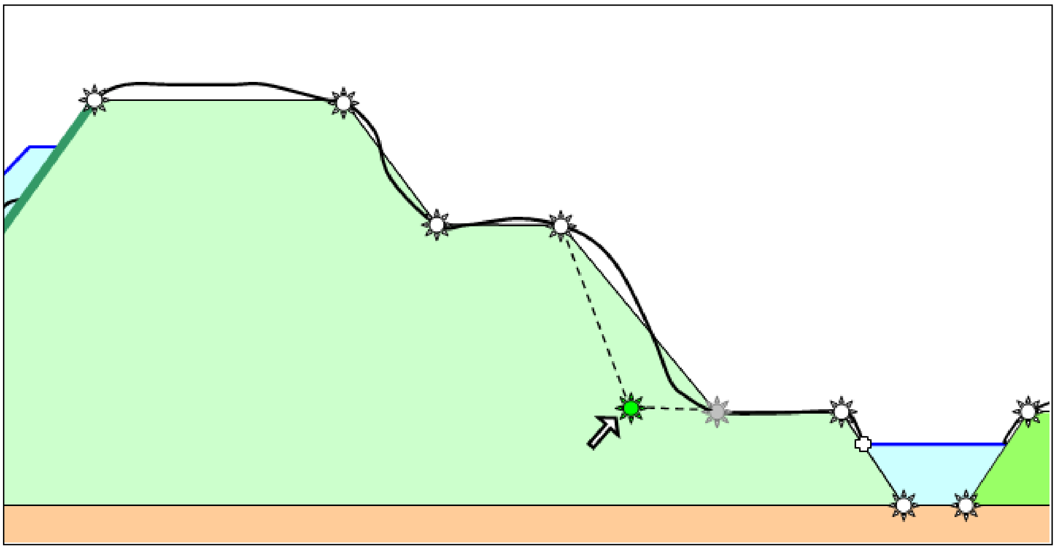


Figure 5.22 Disconnect characteristic point from dike surface line

5.6.4 Property window

Several items in Ringtoets can be selected, either on the map, in the cross section editor, in a table or via the main menu. When selected, their properties are displayed in a property editor. Sometimes several property editors are available for the same item. In that case they are displayed in different tabs in a tab control. Property forms are *not* linked to a Configuration Database.

The following property editors are displayed:

<table>
<tr><th>Item</th><th>Property editor contents</th><th>UC</th></tr>
<tr><td rowspan="2">SoilProfile1D</td><td>Geographical location and list of all soil layers, with top and bottom and assigned soil</td><td></td></tr>
<tr><td>Soil properties assigned to the soil profile and possibility to select another soil. Available soils are retrieved from the soilbase model</td><td></td></tr>
<tr><td rowspan="2">SoilProfile2D</td><td>Geographical location and list of all soil layers with assigned soil</td><td></td></tr>
<tr><td>Soil properties assigned to the soil profile and possibility to select another soil. Available soils are retrieved from the soilbase model</td><td></td></tr>
<tr><td>StochasticSoilProfile</td><td>Geographical location and list of all soil profiles with their probability</td><td></td></tr>
<tr><td>SurfaceLine</td><td>Geographical location and list of all points and their coordinates and characteristic type</td><td></td></tr>
<tr><td>Fetch</td><td>Geographical location and list of all fetch data per wind direction</td><td></td></tr>
<tr><td>Swell</td><td>Swell properties</td><td></td></tr>
<tr><td>Water level setup</td><td>Water level setup properties</td><td></td></tr>
<tr><td>Revetment</td><td>List of all revetment zones with all properties</td><td></td></tr>
<tr><td>Structure</td><td>Structure properties</td><td></td></tr>
<tr><td>Breakwater</td><td>Breakwater properties</td><td></td></tr>
<tr><td rowspan="6">Dike section</td><td>Geographical and administrative information and assessment options (whether to include in assessment).</td><td></td></tr>
<tr><td>Assigned (combined) hydraulic boundaries. In case of combined hydraulic boundaries, a list is supplied with contributions of underlying hydraulic boundaries.</td><td></td></tr>
<tr><td>Soil profile with the possibility to select another soil profile</td><td></td></tr>
<tr><td>Surface line with the possibility to select another surface line</td><td></td></tr>
<tr><td>Failure mechanism specific data for the dike section. Reliability and design point details.</td><td></td></tr>
<tr><td>Probabilistic method and indication whether default is used</td><td></td></tr>
<tr><td rowspan="2">Dike line</td><td>Administrative values of the dike line and a table with combined failure probabilities, per mechanism and combined over all mechanisms</td><td></td></tr>
<tr><td>List with all bending points in dike line.</td><td></td></tr>
<tr><td>Characteristic line</td><td>Meaning of characteristic line and list with all bending points</td><td></td></tr>
<tr><td>Project</td><td><table><tr><td>Attributes</td><td>NL</td></tr><tr><td>Name</td><td>Naam</td></tr><tr><td>Client</td><td>Opdrachtgever</td></tr><tr><td>Project administrator</td><td>Project-administrator</td></tr></table></td><td></td></tr>
</table>

<table>
<tr><th>Item</th><th>Property editor contents</th><th>UC</th></tr>
<tr><td></td><td><table>
<tr><td>Main project database location</td><td>Hoofd projectdatabase locatie</td></tr>
<tr><td>Main project database checked out sections</td><td>Hoofd projectdatabase uitgecheckte delen</td></tr>
<tr><td>Location Hydraulic Boundary database</td><td>Locatie Hydraulische randvoorwaarden database</td></tr>
<tr><td>Location temporary files</td><td>Locatie tijdelijke bestanden</td></tr>
<tr><td>Pre-configured mapping table</td><td>Vooraf geconfigureerde koppeltabel</td></tr>
</table></td><td></td></tr>
<tr><td>Failure mechanism</td><td>General properties of the selected failure mechanism</td><td></td></tr>
<tr><td>Assessment model</td><td>Default properties of the selected assessment model. General calculation options including the calculation scheme and probabilistic method.

For assessment model 2b probabilistic properties are displayed for the selected mechanism.

For 2a and 2b, a list is displayed with all available failure mechanisms, where the user can specify whether it should be used in the assessment.</td><td></td></tr>
</table>

5.6.5 Tables and charts

Tables and charts are displayed with close relationship to each other. Within a table/chart window, both a table and a chart are displayed. The chart is displayed right or below of the table, depending on the available space. The user can switch off one of them if he wishes.

The following data are available in the tables. By default the number of columns equals the number of item properties. Hiding of columns of for example intermediate results is possible.

Item	*Table*	*Chart*	*UC*
Dike sections	Dike sections for the selected failure mechanism. In case no dike division has been set up yet, each dike line is assumed to be a dike section. Group per dike line. The table includes the failure probability for the dike section	The L coordinate indicates the offset along the dike line.	
Dike division	All division points for the current	No chart.	

Item	*Table*	*Chart*	*UC*
points	failure mechanism. Group per dike line		
Dike lines	Contains all failure probabilities valid for the whole dike linel	Bar chart with failure probability	
Charaterisic lines	Displayes meaning of line and allows focusing in map and property editor	No chart	
Soil profiles 1D	All available 1D soil profiles in the soilbase model.	No chart.	
Soil profiles 2D	All available 2D soil profiles in the soilbase model.	No chart.	
Stochastic soil profiles	All available stochastic soil profiles in the soilbase model.	No chart.	
Surface lines	All surface lines in the soilbase model.	No chart.	
Swells	All swell data	No chart.	
Fetches	All fetch data	No chart.	
Water level setups	All water level setup data	No chart.	
Breakwaters	All breakwater data	No chart.	
Structures	All structure data	No chart.	

5.7 Validation

Validation is run automatically after each change in the input data. It runs in a separate thread, so it won't block the application. After validation finishes, a list of messages is displayed. These messages are either errors or warnings. If errors are present, running an assessment is not allowed.

The following validations take place:

Type	*Validation*
Error	Exceedance of minimum or maximum of various objects
Warning	Check if cross sections are linked to one or two HB-output point(s) for level 1 assessment. Note: cross sections without HB-output point(s) can use interpolation (0) to get a characteristic water level and wave parameters.
Warning	Check if cross sections have characteristic points for the foreland and outer dike slope as input for the computations. If not, give a warning that interpolation is necessary.
Error	Check if characteristic cross sections (one for each mechanism section) are linked to one or two HB-output point(s) for level 2a and level 2b assessment.
Warning	Dike section consists of complete dike ring
Error	Dike surface line validation in the Cross section editor for Overflow and Wave overtopping. Foreland: - The horizontal surface point coordinates must increase going from start foreland to outer dike toe (important for tabular input).

Type	*Validation*
	- Slopes steeper than 1 to 10 are not allowed (both rising and downward parts); gentle slopes are allowed. - The minimum distance between surface points is 10 m: too much detail in foreland is not allowed. - The surface points cannot go lower than the first foreland point. Dike: The dike consists of one or multiple dike line segments. The segments are either *slope* segments or *berm* segments: - Slope segments have a minimum inclination of 1 to 8. - Berm segments have a minimum inclination of 1 to 100 and a **maximum inclination of 1 to 15. As a result, dike segments between 1 to 15 and 1 to 8 are not allowed. These 'intermediate' area's cannot be calculated by the wave run-up routine. - A maximum of *two berm* segments are allowed. - The minimum distance between dike points is 2 meter. Too much detail in the dike profile is not allowed. - The horizontal point coordinates must increase looking from dike toe to dike crest. - The vertical point coordinates must increase looking from dike toe to dike crest. - Slope segments are steeper than 1 to 8 but cannot be steeper than 1 to 1 (almost vertical slopes or vertical walls are not allowed). - The first and last slope section must be steeper than 1 to 8. Revetment: - A revetment segment, to determine the roughness, cannot be smaller than 1 meter. - The revetment cannot be positioned lower than the lowest slope point or lower than the endpoint of the foreland. - Overlapping revetments segments are not allowed, gaps between revetments are. Note: These revetment segments validation rules apply to the main mechanism Overflow and Wave Overtopping and not for the main mechanism Revetment. The main mechanism Overflow and Wave Overtopping just need the revetment surface roughness to calculate the hydraulic conditions on the outer dike slope.

5.8 Assessments

5.8.1 Assessment Level 0

Some failure mechanisms are irrelevant for a certain stretch at a certain location. In Assessment level 0 the user can exclude these failure mechanisms for further assessments.

5.8.1.1 Execute Level 0 assessment

Starting point for level 0 assessment is imported dike key-data as described in §5.3.1. In the map-editor the user can view that data such as the dike line with the characteristic lines and the cross-section points. With the basic GIS-functions and controls in the map editor, the user can open the dike cross-sections in the cross section editor. The expert can then view and inspect the dike geometry in the cross section editor.

The level 0 assessment must be performed for each failure mechanism. The user can switch between failure mechanisms by the drop down box failure mechanisms located on top of the map editor.

The expert assesses the relevance of a failure mechanism based on dike geometry, dike location and expert judgment. When a failure mechanism is assessed as not relevant, the dike section will be marked as a level 0 assessment section. The cross sections will get a different marking in the map editor. The map legend must link that specific mark with the status ‘Level 0’. The failure probability of a Level 0 section will be assumed to be zero. The remaining cross sections are input for further assessment (level 1 or 2).

The user will be able to mark a dike section as level 0 in four different ways: in the cross section editor, in the map editor, in the property editor and in a table. Methods to mark a dike section as Level 0 section include the following:

- By a button in the cross section toolbar.
- In the map editor by drawing a box with the mouse pointer. The cross sections inside the box will become ‘selected’. With a button on the map editor toolbox, the user can mark the selected cross sections as Level 0.
- With a check box in the property editor of an activated (selected) cross section.
- In a table that lists all available cross sections. A column ‘Level 0’ will be available in that table, giving the user the possibility to set the Level 0 status for multiple cross sections in one go.

Figure 5.23 Activity diagram for a level 0 assessment (relevance check)

5.8.2 Assessment Level 1

A Level 1 assessment is a simple assessment (Table 1.1) based on deterministic decision rules for different failure mechanisms. Input for the dike strength calculations are characteristic points in the dike geometry but also other variables like entrance points and Piezometric heads. Most input variables for the failure mechanisms, both load and strength, are imported or inputted as key-data at the start of the project.

5.8.2.1 Execute level 1

Assessment Level 1 is a simple assessment based on (deterministic) design rules. The assessment is performed per mechanism at *cross section* locations. The assessment will only be applied to cross sections that are not marked with a level 0 status.

Ringtoets will call Hydra-Ring for the computation of the characteristic water level and wave parameters per cross section, usually in combination with an overtopping calculation. For this purpose a schematization of both the foreland and outer dike slope are necessary. The user can select certain cross sections for this first hydraulic boundary schematization. For the cross sections in between, Ringtoets will use interpolation to determine the hydraulic boundary conditions. Ringtoets will need to pass data from the project database to Hydra-Ring and vice versa.

Figure 5.24 Activity diagram for a level 1 assessment

5.8.2.2 *Inspect level 1 results*

Ringtoets will execute a level 1 assessment at the cross sections that were not marked by the user with ‘level 0’. Level 1 is a simple, deterministic assessment based on decision rules. The result indicates only if cross section passes the assessment or not. Ringtoets will mark the cross sections that pass with a ‘level 1’ status. The remaining cross sections will be marked for further assessment (‘level 2’). The results will be visible if ‘Assessment Level 1’ is activated in the Ringtoets toolbar.

The user can inspect the results in the Map editor. A button ‘Show results’ on the map editor toolbar displays the results on the dike line per cross section. The possible statuses are 0 (irrelevant for this mechanism), 1 (passing a level 1 assessment), or 2 (level 2 assessment is required). The same information will also be available in the table presentation.

Ringtoets will also store the maximum allowed failure probability per level 1 approved mechanism and cross section, unless this value is zero. The user can inspect these values in a table presentation. The maximum failure probability will be affected by the dike length associated to a cross section.

5.8.3 Assessment level 2a

5.8.3.1 Additional schematization for level 2 assessment

Level 2 is a detailed analysis using a semi-probabilistic calculation (2a) or a full probabilistic calculation (2b). The difference with the previous assessment levels is that the level 2 assessments use *mechanism sections* instead of cross sections.

A mechanism section is a stretch of a flood defense with more or less homogeneous properties and boundary conditions for the considered mechanism. A mechanism section is built from multiple, adjacent cross sections. Initially the entire dike line is one mechanism section. The user can split one mechanism in two separate mechanism sections by adding a point on the dike line. Merging of mechanism sections is possible as well.

Import of existing mechanism sections divisions will also be possible, eventually in combination with manual adjustments. For the revetment mechanisms branch, Ringtoets will automatically propose a first distribution, based on the location of different revetment zones.

For every mechanism section the user must select one *characteristic cross section.* The properties of that cross section will be used as input for following level 2a assessments. By default, Ringtoets will automatically link the cross section that is most close to the middle of the centerline of the dike section. Manual selection of another cross section is possible.

5.8.3.2 Execute level 2a assessment

Level 2a assessment is a semi-probabilistic assessment. The assessment is per mechanism section. If the assessment is positive, the failure probability is below a certain maximum derived from the failure probability budget by using characteristic values for strength and loading, in combination with partial safety factors. The length of a single mechanism influences that failure budget (length effect) via partial safety factors.

Figure 5.25 Activity diagram for a level 2a assessment

5.8.3.3 Inspect level 2a results

The result of a 2a assessment is a check on the Factor of Safety (FOS). The results show whether the FOS is sufficiently large enough (‘OK’,) or not (‘Not OK’). The user will also have the possibility to inspect the actual calculated FOS.
The results will be shown in the Map Editor where mechanism sections are indicated with a green color (‘OK’) or orange color (‘Not OK’). The user can inspect the results per mechanism (pull down menu in Ringtoets toolbar). The mechanism sections with a green color are either stretches marked as ‘level 0’, ‘level 1’, or ‘level 2a OK’. The ‘level 2a Not OK’ stretches will have the orange color. Those sections are input for the 2b assessment.

In the ‘Combined’ mode (combined for all mechanisms) the map editor shows the results projected on *combination sections*. Ringtoets creates the combination sections by projecting the begin and end points of *all* mechanism sections of *all* mechanisms on the dike (Figure 2.5). The ‘Combined’ mode can be activated by a button on the Ringtoets toolbar. This mode is additional to the failure mechanisms (e.g. Overtopping | Revetment | Piping | Combined).

The *table* below the bottom of the Map Editor shows the results per mechanism section or per presentation section. If a mechanism is activated (in the pull down menu), there will be at least columns with the mechanism section’s name (Id), the assessment level (0, 1, 2) and level 2a results (OK, Not OK). If the item ‘Combined’ is selected, the table shows the presentation section Id’s and the level 2a results (OK, Not OK).

The FOS can be displayed per failure mechanism as well (combined for *mechanism sections*). In the Map Editor the user must select the ‘FOS’ button. The color of the mechanism sections and the legend will change to a ‘FOS’ display. Additionally the actual, digital FOS value can be displayed in a mechanism section *label*. The FOS value can be displayed in the table presentation.

Detailed assessment results for overtopping/overflow will also be presented in the table presentation.

5.8.4 Assessment Level 2b

Assessment Level 2b is full probabilistic check. Initially the 2a mechanism sections that did not pass the semi-probabilistic check are input for 2b. Additional input (probabilistic data) is necessary but not mandatory. The level 2b results can be displayed on user defined *presentation sections.*

5.8.4.1 Additional schematization for level 2b assessment

By default the input for level 2b are the level 2a section that did not pass the semi-probabilistic check. Initially all mechanism sections that did not pass the semi-probabilistic test are input for the full probabilistic assessment. Additionally, it will also be possible to manually select mechanism sections with the status ‘level 1 OK’ or ‘level 2a OK’ sections as input for the level 2b assessment. With the check box ‘Select all’ the user can select all available mechanism sections as input for level 2b (except for level 0 stretches) at once. This check box is located in the level 2b assessment calculation form (§ 5.8.4.2).

Ringtoets can accept a stochastic definition for many model parameters. These model parameters are imported as key-data and/or edited in property forms and tables.

The user must modify (move) characteristic points if they don't comply with the (more) stringent constraints. Probabilistic input is possible for the mechanisms overflow/overtopping and revetment. At writing of this report, this functionality will not be implemented yet.
It is possible to input stochastic soil profiles for piping. For one cross section the user can for example select three 1D soil profiles from the soil database. Each profile gets a certain probability and the summed probabilities is 100%. If only one soil profile is available, it automatically has a probability of 100%.

The level 2b assessment computes the combined failure probabilities of all failure mechanisms on *presentation sections*. Presentation sections are groups of the combination sections from level 2a. The user must define the presentation sections in advance of the level 2b calculation. By default the presentation section division is equal to the combination section division from level 2a.

To combine level 2b results with level 1 and level 2a results, the failure probability budgets of these dike stretches are needed.

5.8.4.2 *Execute level 2b assessment*

Level 2b assessment is a full probabilistic assessment, which means that stochastic variables are used for load and strength computations. Note that it is not mandatory to model all parameters as stochastic variables. Instead, Ringtoets can also use for selected parameters also the same unfavorable values as in a semi-probabilistic analysis. A level 2a assessment can be easily replaced by a level 2b assessment, as no additional data is needed. In case of a combination with level 1 assessed parts, Ringtoets wil need to reduce the admissible failure probability for level 2b, if the maximum failure probability of some level 1 assessed parts is significantly larger than zero.

Ringtoets will call Hydra-Ring twice for the execution of Assessment level 2b.

- First for the calculation of failure probabilities per mechanism section (the mechanism section loop is expected to be part of Hydra-Ring). Output are the Failure Probabilities (FP) and design points per mechanism section.
- Second for combination of failure probabilities to presentation sections and to combinations of presentation sections.

Ringtoets will need to pass data from the database to Hydra-Ring and vice versa.

Figure 5.26 Activity diagram for a level 2b assessment

The following classes are involved in controlling HydraRing:

Figure 5.27 Class diagram for controlling HydraRing

5.8.4.3 *Inspect level 2b results*

Output of level 2b assessment are failure probabilities and design points. Ringtoets combines the FP of separate mechanism sections to FP for presentation sections and the total dike ring.

The user can inspect the FP per mechanism section in the Map Editor. The Map Editor shows the FP on the dike line for each failure mechanism section with a color. The FP value can be displayed in a mechanism section label. With a pull down menu the user can switch between the results for different mechanisms. In level 2b the pull down menu also has the item ‘Presentation sections’, showing the FP per presentation section. The results are also visualized in the dike line graph.

If ‘Presentation sections’ is selected, the Map Editor shows the total FP for the (entire) dike ring. The total FP as a numerical value is shown in a label located at the center of the dike ring. The color scheme is similar to the previous used FP legend colors.

If the user double clicks the dike line, a *property form* opens. The tab 'Level 2b' in that property form will show the total FP per failure mechanism and the (entire) dike ring.

The numerical values of the FP per mechanism sections are also shown in the *table* presentation below the Map Editor. The values are updated whenever the user selects another mechanism in the pull down menu. The table also shows the previously used *failure probability budget* for level 1 and level 2a sections. If the user chooses 'Presentation section', the table shows the FP for presentation sections. In this mode, the table not only presents the FP values but also the *available* failure probability budget per presentation section.

The table lists the design points as well. A design point is a collection of values of stochastic variables. The number (columns) of displayed stochastic variables may be limited to key-variables if there are too many. The user can set the application in a mode to display design point values. Then all property editors and tables show data values according to the design points. This is taken care for by the StochasticParameter class.

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A Glossary of terms (English to Dutch)

(Terms in italic are not used in the current report)

English	Dutch	Description
APT	*APT*	*Arbitrary point in time – refers to a alternative method for FBC, modelling the time position in a trapezoidal shaped evolution of a discharge wave or lake level by using an additional stochastic time variable.*
Assessment	Toets	refers to the assessment of flood defences to determine if they comply with legally mandated protection levels during the assessment period
Assessment water level	Toetspeil	Characteristic water level associated with a legally mandated exceeding probability at the end of the assessment period.
Block	*Blok*	*Refers within the FBC calculation scheme to the rectangular shape of a temporal process, such as a discharge wave.*
Block duration	*Blokduur*	*The width (in time) of a temporal process represented by a block*
Central form	Centrale dialoog	The central form of the program screen.
Characteristic lines	Karakteristieke lijnen	Lines parallel to the dike, which combine a certain characteristic point in different dike cross sections.
Characteristic value	Karakteristieke waarde	Value with a certain exceedance probability
Combining	*Oprollen*	*Combining failure probabilities for elements with unequal design points, using the Hohenbichler method*
Combination sections	Combinatie vakken	Dike sections, with a division following from the joined mechanism sections, for a semi-probabilistic assessment of combined mechanisms
Cross section	Doorsnede	A dike cross section
D	*Dagenlijn*	*D(Q). The average number of days per winter period that the discharge Q exceeds a certain value*
DAM	DAM	Dike strength Analysis Module, for automated schematization, analysis and design, based on geotechnical failure mechanisms.
Design point	Illustratiepunt /Ontwerppunt	The combination of parameters at failure with the highest probability. The FORM method linearizes the Limit State function in this point, after estimating it by a gradient search method.
Design water level	*MHW, Ontwerppeil*	*Characteristic water level associated with a legally mandated exceeding probability at the end of the design life*
Detailed assessment	Gedetailleerde toetsing	A semi-probabilistic or probabilistic assessment (level 2a or level 2b), based on failure mechanism models requiring detailed input.
Dike	Dijk	A dike as part of a defence system.

Dike line	Dijk lijn	The dike location line, usually connecting the points at the approximate centre of the dike crest.
Dike point	Dijkpunt	Point on dike line marking the begin/end point of a dike section.
Dike ring	Dijkring	A dike ring is a continuous line of flood defences (dikes, dunes, structures, barriers or high ground), protecting a certain region.
Dike section	Dijkvak	A part of the dike for which strength and load properties are homogeneous
Discharge	*afvoerdebiet*	*The river discharge Q*
Discharge peak	*Afvoerpiek*	*The highest discharge in a modelled discharge wave*
Discharge wave	*Afvoergolf*	*The assumed development in time of the river discharge during a high water period.*
Drop down menu	Drop down menu	A drop down menu with a number of predefined selection options.
DS	*Directional Sampling*	*Monte carlo directional sampling*
Dune	Duin	Dune as part of a defence system.
Discharge exceedance frequency curve	*Werklijn, Frequentielijn*	*F(Q).The average number of occurrences per winter period that the discharge Q exceeds a certain value*
Failure Mechanism	Faalmechanisme	A fundamental process or defect causing failure of the water retaining function. Examples are: overtopping/overflow, slope instability, piping, revetment failure, dune erosion etc.
Failure mechanism model	Faalmechanisme model	A failure mechanism can have more failure mechanism models. The failure mechanism piping can have one or more sub soil models.
Failure probability (FP)	Faalkans	The annual probability that a flood defence fails, i.e. that water enters the protected area.
FBC	*FBC*	*calculation scheme named after Ferry, Borges and Castanheta, with a blockwise description of the temporal evalution of a discharge wave or lake level..*
Fetch area	Strijklengte	The fetch area per wind direction for the development of wind waves according to the Bretschneider model.
File format	Bestandsformaat	File formats are defined for specific data sets.
Flood defence	Waterkering	A water retaining object (dike, dune, structure), protecting the hinterland.
Foreland	Voorland	Area outside the dike, from dike toe to (hydraulic boundary) point with undisturbed hydraulic conditions.
FORM	*FORM*	*Probabilistic method: First Order Reliability Method, determines the so-called design point and associated FP using iterative linearization of the limit state function*
FOS	Veiligheidsfactor	Factor of Safety. Ratio between allowed and actual value of a certain load type.

FP budget	Faalkansenbudget	The allocated allowed failure probability for different mechanisms and sections, in case of a sem-probabilistic assessment
GIS	GIS	Geographic Information System
GIS-layer	GIS kaartlaag	Layers in a GIS map of a certain theme.
GIS-map	GIS kaart	A map with geographic background and objects.
Heave	Opbarsten	Mechanism of heave of the cover layer, due to the upward pore pressure in the aquifer underneath .
Hydraulic load	Hydraulische belasting	Load of a construction due to hydrodynamic processes.
Hydrodynamic database	Hydraulische randvoorwaarden	Database with the hydrodynamic parameters.
Key data	kerngegevens	Key data, for setting up a dike schematisation. Most key data will be imported from existing databases, maintained by the water boards.
Length effect	Lengte effect	The increase in failure probability that results from considering longer stretches of dike (or dunes)
Limit State Function (LSF)	*LSF*	*Describes the interface between failure and non-failure for different combinations of stochastic parameters*
Loop sequence	*Rekenschema*	*Refers to the sequence of loops (e.g. over time periods, wind directions and mechanisms) in programming code*
MC-C	*MC-C*	*Probabilistic method: Crude Monte Carlo sampling.*
MC-IS	*MC-IS*	*Probabilistic method: Monte Carlo importance sampling*
Mechanism	mechanisme	see Failure mechanism
Mechanism section	Mechanismevak	A stretch of a flood defence with more or less homogeneous properties and boundary conditions for the considered mechanism.
Menu bar	Menubalk	
N	*Overschrijdingsduurlijn*	*Duration line. N(Q) = D(Q)/F(Q). The average duration of the period in which Q exceeds a certain value*
Navigation pane	Navigatie paneel	Navigation pane with lists of editable GIS-objects such as cross sections, dike line and hydraulic boundary points.
NTI	*Numerieke tijdsintegratie*	*Refers to a method for modelling the shape of a temporal evolution of a discharge wave or lake level, by discretizing it into sections of width Δt, and combining the failure probability contributions of all sections. The combination of NTI with NI gives characteristic water levels equal to the Hydra's.*
NI	*Numerieke integratie*	*Probabilistic method: Numerical Integration. Discretizes random variables and for each combination computes the probability of occurrence and subsequently sums over all combinations that led to failure*

Overflow	Overloop	failure mechanism that occurs when the water level is higher than the crest height of the defence
Overtopping	Overslag	failure mechanism that occurs when the waves run over the crest height of the defence (water level + wave > crest height)
Piping	Piping	The mechanism that causes loss of stability by internal erosion
Presentation section	Presentatievak	Sections consisting of one or more combination sections, for the purpose of presenting the combined contribution from different mechanisms in case of a probabilistic analysis.
Probabilistic analysis	Probabilistische analyse	Probabilistic determination of failure probabilily, using stochastically distributed variables for loading and strength.
Project database	Project database	Database with all project data, except for the results database and hydrodynamic database of the active project.
Relevance check	Relevantie toets	Relevance check for a certain failure mechanism for a certain dike section (level 0).
Revetment	Bekleding	Revetment of a dike, defined by different zones, each consisting of a certain revetment type with associated properties.
Screen	Beeldscherm	The screen user interface of the Ringtoets application.
Semi-probabilistic analysis	Semi-probabilistische toets	A deterministic assessment (level 1 or 2a), using conservative characteristic values for loading and strength parameters, together with partial safety factors. The safety factors are calibrated such, that the failure probability will always stay below the allowed value.
Section	vak	Part of the flood defence system with more or less homogeneous loading and strength properties.
Simple assessment	Eenvoudig toetsing	Simple assessment of a dike section (level 1), using failure mechanism models requiring only geometrical data.
Slope instability	Macro-instabiliteit	The mechanism that causes slope shear failure of dike embankments
Structures	Kunstwerken	Civil structures build as part of the defence system.
Sub-mechanism	Deelmechanisme	A submechanism which only causes failure when combined together with another submechanism
Subsoil	Ondergrond	Subsoil of the dike's basement.
Subsoil profile	Ondergrondprofiel	A sequence of subsoil layers, either 1D or 2D.
Subsoil scenario	Ondergrondscenario	A subsoil profile with certain occurrence probability, in case of stochastic subsoil modelling.
Surface line	Dijkoppervlak	The surface line of the dike in the cross section, including the relevant part of the waterbed and the hinterland.
System Architecture	Systeemarchitectuur	The hardware design of an application.
Tab	Tabblad	Tabs are used to switch between different forms.
Tidal period	*Getijperiode*	*A period of (approximately) one tide, relevant in the load modelling for an arbitrary discharge wave*

		shape
Upscaling	*Opschalen*	*Combining failure probabilities for a number of elements (time elements or spatial elements) with equal FP*
XML	XML	Self describing data format, suited for exchange through files or web-services

B Glossary of terms (Dutch to English)

(Begrippen in schuinschrift worden in het rapport niet gebruikt)

Dutch	English	Beschrijving
Afvoerdebiet	*Discharge*	*De rivierafvoer (Q)*
Afvoergolf	*Discharge wave*	*De aangenomen ontwikkeling in tijd van de rivierafvoer gedurende een hoogwaterperiode.*
Afvoerpiek	*Discharge peak*	*The hoogste afvoer in een gemodelleerde afvoergolf.*
APT	*Arbitrary Point in Time*	*Refereert naar een alternatief rekenschema voor FBC, waarin een trapeziumvormig verloop van een afvoergolf of het meerpeil wordt gemodelleerd middels een extra stochastische variabele voor het evaluatietijdstip binnen de afvoergolf.*
Beeldscherm	Screen	Het beeldscherm van het programma Ringtoets
Bekleding	Revetment	Bekleding van een dijklichaam. Deze bestaat doorgaans uit verschillende geometrische zones, met elk een bepaald bekledingstype en daaraan verbonden eigenschappen.
Bestandsformaat	File format	Bestandsformaat, meestal gedefinieerd voor de uitwisseling van specifieke gegevens.
Blok	*Block*	*Refereert binnen het FBC rekenschema naar de rechthoekige vorm van een tijdsafhankelijk proces zoals een hoogwatergolf.*
Blokduur	*Block duration*	*De duur (in de tijd) van een tijdsafhankelijk proces dat geschematiseerd is als een blok.*
Centrale dialoog	Central form	Centrale dialoog van het programma beeldscherm.
Combinatievakken	Combination sections	Vakindeling die resulteert uit het “opbossen” van de indelingen voor verschillende mechanismen, ten behoeve van een semiprobabilistisch toetsresultaat voor gecombineerde mechanismen.
Dagenlijn	*D(Q).*	*D(Q). Het gemiddelde aantal dagen in de winterperiode waarbij de rivierafvoer een bepaalde waarde overschrijdt.*
DAM	DAM	Dijksterkte Analyse Module voor geautomatiseerde schematisatie, analyse en ontwerp op basis van geotechnische faalmechanismen. DAM wordt ontwikkeld onder regie van STOWA
Deelmechanisme	Sub-mechanism	Een deelmechanisme dat alleen kan leiden tot falen in combinatie met een ander deelmechanisme.
Deterministische toetsing veiligheid	Deterministic safety assessment	De deterministische toetsing van de dijkveiligheid, gebaseerd op deterministisch vastgestelde processen, vaak leidend tot ruimte (conservatieve) veiligheidsmarges.
Dijk	Dike	Een dijk of dijklichaam

Dijklijn	Dike line	De hartlijn van het dijklichaam, meestel gelegen in het midden van de dijkkruin.
Dijkoppervlak	Surface line	De oppervlaktelijn van een dijk in een dwarsdoorsnede, inclusief het relevante deel van het waterbed en het achterland.
Dijkpunt	Dike point	Punt op dijklijn die het begin/einde van een dijkvak markeert.
Dijkring	Dike ring	Een dijkring is gedefinieerd als ondoorbroken lijn van waterkeringen (dijken, duinen, stuwen of hoge gronden), die een bepaald gebied beschermt.
Dijkvak	Dike section	Een deel van de dijk (in as-richting) met min of meer homogene eigenschappen en belasting
Doorsnede	Cross section	Een dwarsdoorsnede van de dijk
Drop down menu	Drop down menu	Een keuze menu met vooraf gedefinieerd aantal mogelijkheden.
DS	*DS*	*Probabilistische methode: Monte Carlo directional sampling*
Duin	Dune	Een duin als onderdeel van een waterkering.
Eenvoudige toetsing	Simple Assessment	Een eenvoudige toetsing (level 1), met faalmechanismodellen waarvoor doorgaans geometrische informatie volstaat
Faalkans	Failure probability (FP)	Op systeem niveau is dit de jaarlijks kans dat een waterkering faalt, dus dat water het beschermde gebied binnengaat. Hydra-Ring gebruikt een combinatie van technieken om de faalkansbijdragen van verschillende faalmechanismen en dijksecties te combineren.
Faalkansen budget	FP budget	De toedeling van de toelaatbare faalkans over verschillende mechanismen en vakken, voor een semi-probabilistische toets
Faalmechanisme	Failure Mechanism	Een proces dat kan leiden tot het falen van de waterkerende functie. Bijvoorbeeld: overloop/golfoverslag, helling instabiliteit, piping, bekleding falen, duin erosie etc.
Faalmechanisme model	Failure Mechanism model	Het eenvoudige of gedetailleerde model dat wordt gebruikt om het faalmechanisme te beschrijven.
FOS		Zie veiligheidsfactor
FBC	*FBC*	*Ferry, Borges en Castanheta model voor het modelleren van tijdelijke processen binnen een faalkansberekening, zoals PC-Ring dat ook doet.*
FORM	*FORM*	*Probabilistische methode: Eerste orde betrouwbaarheidsberekeningen, bepaalt het ontwerppunt en de bijbehorende faalkans gebruikmakend van iteratieve linearisatie van de faalkansfunctie.*

Gedetailleerde toets	Detailed assessement	Gedetailleerde toets: semi-probabilistisch (niveau 2a) of probabilistisch (niveau 2b). In beide gevallen wordt gebruik gemaakt van een faalmechanismemodel dat gedetailleerde invoer nodig heeft.
Getijperiode	*Tidal period*	*Een periode van getijde periode, relevant voor het modelleren van de vorm van een willekeurige afvoergolf.*
GIS	GIS	Geografisch Informatiesysteem
GIS kaart	GIS-map	Een GIS kaart waarin de gebruiker kan navigeren en objecten bekijken.
GIS kaartlaag	GIS-layer	Kaartlagen in een GIS kaart met verschillende thema's.
Hydraulic Load	Hydraulische belasting	De hydraulische belasting op een dijklichaam.
Hydraulische randvoorwaarden	Hydrodynamic database	De hydraulische belasting zoals vastgelegd in het Hydraulische Randvoorwaardenboek.
Illustratiepunt /Ontwerppunt	Design point	De combinatie van parameters waarbij falen optreedt met de hoogste kans op voorkomen. De FORM methode maakt gebruik van een gelineariseerde faalkansfunctie. Het punt wordt gevonden door het afschatten van de gradiënten in het ontwerppunt.
Karakteristieke lijn	Characteristic line	Lijn parallel aan de dijk lijn, die een bepaald karakteristieke punt in verschillende dwarsdoorsneden verbindt.
Karakteristieke warde	Characteristic value	Waarde met een bepaalde overschrijdingskans.
Kerngegevens	Key data	Onmisbare gegevens voor het opzetten van de dijk schematisatie. Deze kerngegevens worden doorgaans beheerd door de waterschappen, in een GIS.
Kunstwerken	Structures	Civieltechnische constructies die onderdeel zijn van de (primaire) waterkering.
Lengte effect	Length effect	De toename van de faalkans bij toename van de dijklengte.
LSF	*Limit State Function (LSF)*	*Beschrijft de grens tussen falen/niet-falen voor verschillende combinatie van stochastische parameters.*
Macro-instabiliteit	Slope instability	Afschuiven van het dijktalud.
Mechanismevak	Mechanism section	Een dijkvak waarop de sterkte-eigenschappen en belastingvariabelen voor een zeker mechanisme homogeen zijn.
MC-C	*MC-C*	*Probabilistische methode: Crude Monte Carlo sampling.*
MC-IS	*MC-IS*	*Probabilistische methode: Monte Carlo importance sampling*
Mechanisme	Mechanism	Zie Faalmechanisme
Menubalk	Menu bar	Een balk met keuze opties bovenin het beeldscherm.
MHW, Ontwerppeil	Design water level	Waterniveau aan het eind van een ontwerp verbonden aan de wettelijk opgelegde herhalingstijd.

Navigatie paneel	Navigation pane	Navigatievenster met model items van het geopende project.
Numerieke integratie (NI)	*Numerical Integration*	*Probabilistische methode: berekent de faalkans door numerieke integratie over alle stochastische variabelen.*
Numerieke tijdsintegratie (NTI)	*Numerical Time Integration*	*Refereert naar een alternatieve methode voor FBC, waarbij de vorm van het verloop van een afvoergolfof meerpeil wordt gemodelleerd door hem op te delen in stukjes met elk een duur van Δt. De NTI methode in combinatie met NI is vergelijkbaar met de methode die de Hydra's gebruiken voor de berekening van toetspeilen en hydraulische belastingniveaus.*
Ondergrond	Subsoil	Ondergrond van het dijklichaam.
Ondergrondprofiel	Subsoil profile	Opbouw van de ondergrond in grondlagen (1D o f 2D).
Ondergrondscenario	Subsoil scenario	Ondergrondprofiel met een bepaalde kans op voorkomen in de ondergrondmodellering.
Opbarsten	Heave	Opbarsten van de deklaag door opwaartse grondwaterdruk in de onderliggende watervoerende laag.
Oprollen	*Combining*	*Combineren van faalkansen voor elementen met ongelijke ontwerppunten, gebruikmakend van Hohenbichler*
Opschalen	*Upscaling*	*Combineren van faalkansen voor een aantal elementen (tijd of ruimte elementen) met gelijke faalkansen.*
Overloop	Overflow	Faalmechanisme dat optreedt wanneer het water niveau hoger is dan de dijkkruin.
Overschrijdingsduurlijn		*N(Q) = D(Q)/F(Q). De gemiddelde duur van een periode waarin Q een bepaalde waarde overschrijdt.*
Overslag	Overtopping	Faalmechanisme dat optreedt als golven over de dijkkruin slaan.
Piezometric head	Stijghoogte	Stijghoogte grondwater in een bepaald punt of van een bepaalde laag.
Piping	Piping	Het mechanisme dat leidt tot stabiliteitsverlies door interne erosie.
Presentatievakken	Presentation sections	De onderverdeling van de dijk in presentatievakken , voor combinatie van de faalkansbijdragen van verschillende mechanismen (niveau 2b). Een presentatievak bestaat uit een of meer combinatievakken.
Probabilistische analyse	Probabilistic analysis	Een berekening van de faalkans, gebaseerd op stochastische verdelingen van variabelen voor belasting en sterkte.
Project database	Project database	De database met daarin de projectgegevens van het geopende project.
Rekenschema	*Loop sequence*	*Refereert naar de volgorde van rekenlussen (bijv. over de windrichtingen, en over de faalmechnismen) in de programma code.*
Relevantie toets	Relevance check	Relevantie toets voor een bepaald mechanisme langs een dijkring (niveau 0).

Semi-probabilistische toets	Semi-probabilistic assessment	Een deterministische toets (niveau 1 en niveau 2a), met conservatieve karakteristieke waarden voor belasting en sterkte variabelen, in combinatie met partiële veiligheidsfactoren. De veiligheidsfactoren zijn zo gekozen dat de faalkans altijd beneden een toelaatbare waarde blijft.
Strijklengte	Fetch area	De strijklengte per windrichting voor het ontwikkelen van windgolven, voor het Bretschneider model.
Systeemarchitectuur	System architecture	Het fysieke ontwerp van een systeem.
Tabblad	Tab	Via tabbladen kan tussen verschillende dialogen worden gewisseld.
Toets	Assessment	Refereert naar de toetsing van waterkeringen om te bepalen of ze voldoen aan de wettelijk vastgelegde normen voor de jaarlijkse faalkans.
Toetspeil	Assessment water level	De karakterististieke waterstand met een jaarlijkse overschrijdingskans gelijk aan de toelaatbare.
Vak	Section	Zie dijkvak
Veiligheidsfactor	Factor of Safety	De veiligheidsfactor is de verhouding tussen de toelaatbare en actuele belasting voor een zeker faalmechanisme.
Waterkering (systeem)	Flood defence (system)	Waterkering (dijk, duin, vaste en bewegende constructies).
Werklijn, Frequentielijn	*Discharge Exceedance frequency curve*	*F(Q). Het gemiddeld aantal keren dat een afvoer een bepaalde waarde overschrijdt in één winterperiode.*
Voorland	Foreland	Gebied buitendijks van de dijk vanaf de teen tot aan het (hydraulische randvoorwaarde) punt met ongestoorde hydraulische condities.
XML	XML	Zelfbeschrijvend data formaat, geschikt voor uitwisseling via files of via web-services