PEARL KB

The PEARL Knowledge Base

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pearl

Preparing for Extreme And Rare events in coastaL regions

Authors: George Karavokiros, Archontia Lykou and Christos Makropoulos (NTUA)

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Abstract (for dissemination, 100 words)	The PEARL KB is a flexible and easy to use Knowledge Base that allows users to navigate from their observed problem to a selection (filtering) of possible options/interventions worth considering. It consists mainly of a) a component to calculate the Flood Resilience Index (FRI) and assess the vulnerability of a city against extreme events, b) search functionality enabling the identification of engineering, environmental and operational measures for adaptation and mitigation, c) possibility to inspect the results of documented applications of resilience measures around the globe and d) a repository of publications metadata and other sources that describe resilience measures and document their effectiveness.
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Abbreviations

CDM	Conceptual Data Model
CSS	Cascading Style Sheets
HTTP	Hypertext Transfer Protocol
FOSS	Free and Open Source Software
FRI	Flood Resilience Index
LAA	Learning and Action Alliance
ORM	Object-Relational Mapper
PEARL	Preparing for Extreme And Rare events in coastaL regions (Project acronym)
PEARL KB	PEARL Knowledge Base
VM	Virtual Machine
WSGI	Web Server Gateway Interface

1 Introduction

Decision support and policy development for strengthening resilience of coastal regions is one of the main activities of PEARL, within which a shift from a reactive decision environment to an interactive one is being undertaken, on the basis of the latest thinking in flood management. Towards that aim, the PEARL intelligent Knowledge Base of resilience strategies has been developed which allows end-users to navigate from their observed problem to a selection (screening) of possible options/interventions worth considering (through modelling or other work).

Assisting in the navigation from the statement of a problem towards the identification of suitable measures for more detailed examination, the PEARL Knowledge Base has been designed to target a wide audience including the scientific community, civil societies, policy makers and local government. Incorporating also into the knowledge base applications of resilience measures i.e. real case studies, modelled/simulated case studies or even prototypes/lab physical models, lessons learned might be extracted by the alternative and/or combined interventions, as well as knowledge of "suitability" of each measure (or combination of measures) per type problem, taking also into consideration restrictions which might be imposed e.g. by spatial scale or land uses of measures' implementation.

This document describes the PEARL Knowledge Base (PEARL KB), a software system which is the actual deliverable D5.3 of the PEARL project. According to the Description of Deliverables for WP5, D5.3 is described as follows: "*The PEARL intelligent knowledge-base of resilient strategies: The knowledge base will allow end-users to navigate from their observed problem to a selection (screening) of possible options/interventions worth considering (through modelling and other work). The end user will be assisted in navigating from the statement of the problem towards the identification of suitable measures for more detailed examination*".

PEARL KB has been developed by the National Technical University of Athens for the PEARL project. It can be accessed through the following URL:

http://pearl-kb.hydro.ntua.gr/

In the following sections a description PEARL KB is given. More specifically, section 2 describes the system architecture focusing on its components and concepts. The next section 3 is a user guide of PEARL KB which introduces to the reader the public pages of the application, while section 4 describes the administration pages of PEARL KB, through which authorized users can add new content to the Knowledge Base and modify existing data.

2 System architecture

2.1 System components

PEARL KB uses established, state of the art technologies. Figure 1 depicts the main components of PEARL KB. It has been built on top of the well-established, object-relational database management system (RDB) **PostgreSQL**. It is capable to handle workloads of large applications with many concurrent users, while it comes with a free and open source license (FOSS), as all other software components of the PEARL KB. PostgreSQL is a cross-platform database and at the same time easily expandable and supported by a variety of software tools and frameworks, one of which is Django.

Django is used as the web framework of the PEARL KB. It is capable to support complex database-driven websites and includes an object-relational mapper (ORM) that mediates between data models, defined as classes of the programing language **Python**, and PostgreSQL. In essence, Django allows designing databases at the conceptual data model level, hiding the underlying physical data model and making the Database Management System exchangeable. Django expands the possibilities of processing data retrieved from the RDB in response to HTTP requests and separates the logic from the presentation layer by supporting a flexible and efficient template system that controls the presentation of web applications.

The Web Server Gateway Interface (**WSGI**) is a simple and universal interface between the web server and applications or frameworks based on Python programming language. WSGI allows developers to select a web server independent from the underlying framework as long as it is WSGI compatible.

Apache, as the web server of choice for PEARL KB processes requests via the HTTP protocol in a way that separates dynamic from static content. Requests for content stored in the database are handled by the Django framework while **static content** (e.g. images, CSS, javascript library) is retrieved directly from the file system of the machine.

All components and services of the application are currently running on a virtual machine (VM) hosted by the Greek Research and Academic Community.

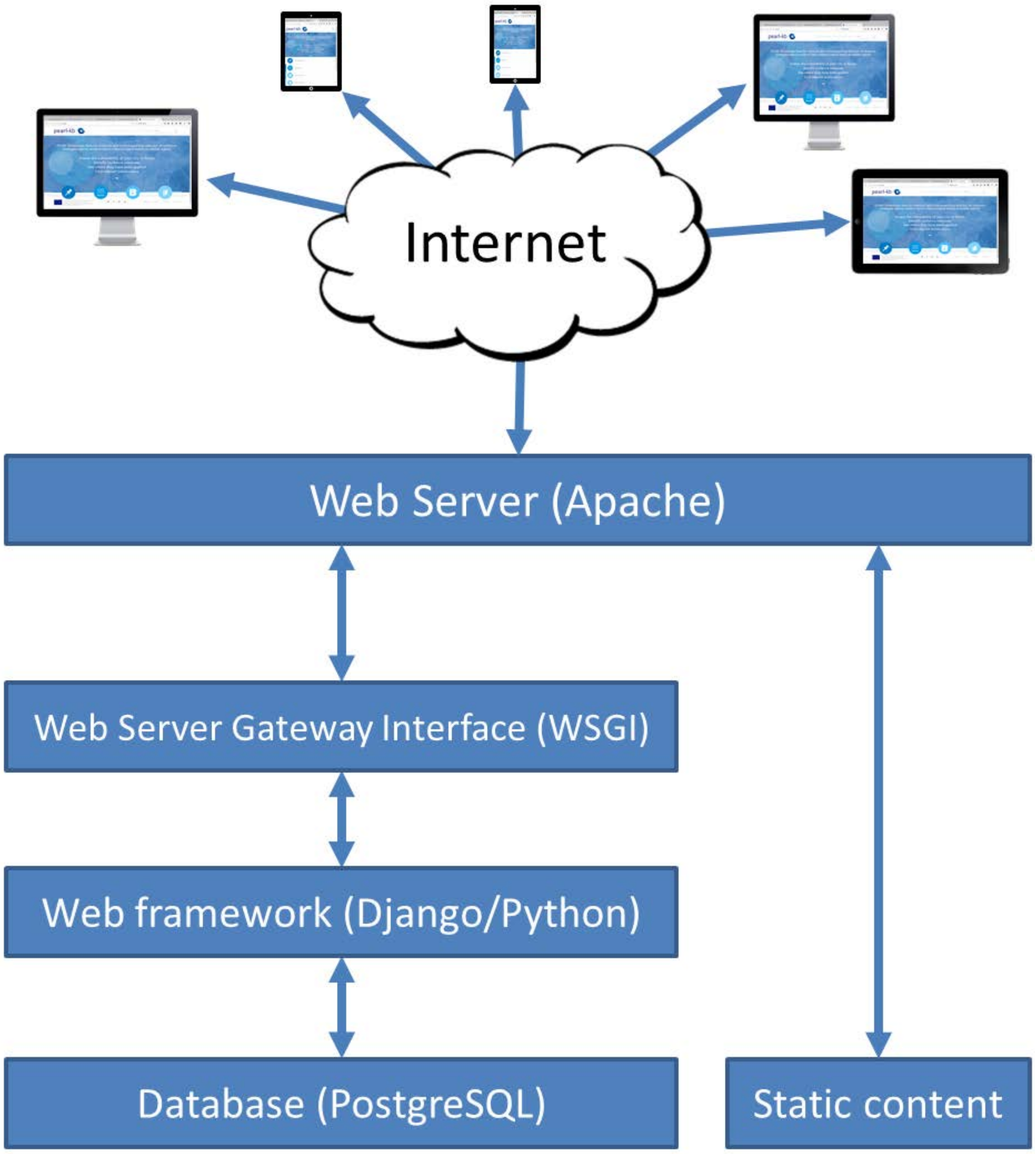


Figure 1: Basic system architecture of PEARL-KB

2.2 Conceptual Data Model

The diagram in Figure 2 illustrates the most important parts of the PEARL KB Conceptual Data Model (CDM). Entity classes shown in red background represent the main classes, while the remaining lookup classes have an auxiliary function.

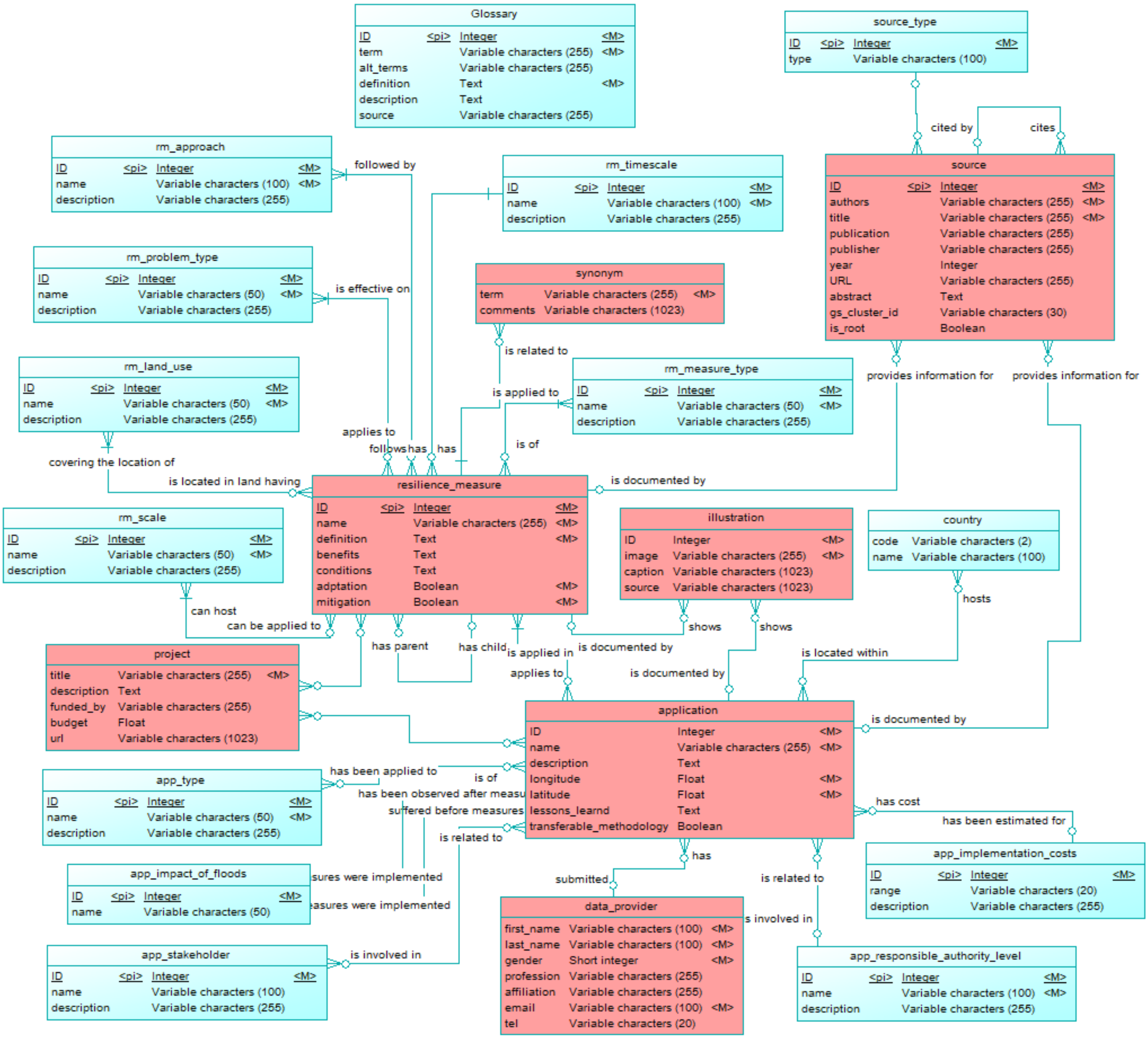


Figure 2: Main part of the PEARL KB CDM

2.2.1 Resilience measures

This is one of the main entity classes of PEARL KB. It includes measures, strategies and other options for flood management that could potentially help improving the resilience of a city against floods. Measures stored in the KB may address problems originating from one or more flood types (coastal, fluvial, pluvial groundwater and drain) and may be suitable for one or more scales, from building up to subcatchment. PEARL KB distinguishes between three general measure types: a) engineering, b) environmental and c) operational and measures may be suitable to various kinds of land use.

Some measures are also known with another name. **Synonyms** to a resilience measure are documented in separate table which is linked with the measure entity. Next to synonyms, measures may have one or more relations to a number of other entities such as case studies (applications), illustrations, sources and projects, as described in the next sections.

2.2.2 Applications (Case studies)

These are applied configurations of resilience measures. Usually, these are case studies on the field, but other types of applications such as modelled/simulated case study or lab prototypes are supported. Several other structured information related with applications of measures are documented depending on the purpose and the scope of the application as well as the outcomes.

Next to resilience measures, application entities may be related to projects, data providers and illustrations in a many-to-many relationship.

2.2.3 Illustrations

Representative illustrations of resilience measures or their applications in a specific location are stored in PEARL KB. However, the database of PEARL KB stores only the metadata of illustrations while the actual illustration files are stored directly in the file system and linked with the related illustration entity. This option provides more flexibility in the management of the database over the alternative all data stored within the database.

2.2.4 Sources

Sources refer to any kind of documentation of resilience measures and applications which have been documented in PEARL KB. The source data and type (e.g. journal articles, books, project reports, etc.) are reported as well as possible external links.

2.2.5 Projects

Many of the data collected in the Knowledge Base originate from other projects. This entity class serves as reference to these projects and does not provide extensive information of projects.

2.3 Backup plan

A **backup plan** has been developed and is in operation having the following main characteristics:

- A backup of the Knowledge Base is taken once per day and kept for one week
- The last backup of every week is considered the weekly backup and kept for a month before recycling
- The last backup of every month is considered the monthly backup and kept for six months before recycling
- Backups are stored in a location which differs physically from the system in operation and the data centre of the backup server is managed by another service provider
- The backup procedure is automated using the backup software *rsnapshot*[1].
- In case of an emergency, system operation can be restored within two working days using the last available backup

[1] http://rsnapshot.org/

3 User’s guide

The main objective of the PEARL KB front end is to support the users in their aim to identify resilience strategies and specific measures that are suitable for their region against extreme events. Appropriate functionality of the website has been developed to guide the users in the following activities:

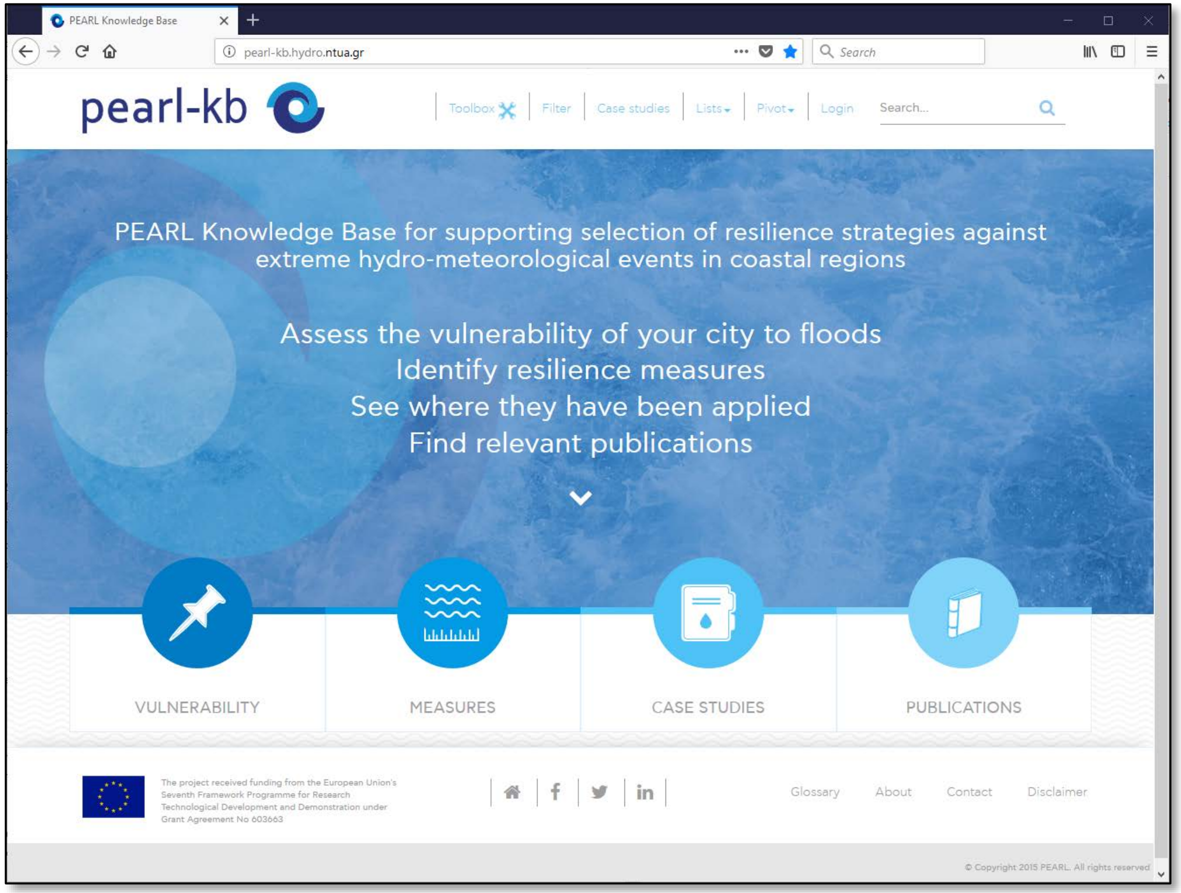
Assess the **resilience** of their city to floods by calculating the Flood Resilience Index (FRI) and identifying dimensions and specific fields where the coastal region is particularly vulnerable.

Once the main vulnerabilities have been recognized, the user may proceed in identifying **measures and strategies** which may help improving the city’s resilience. The PEARL KB supports this transition by linking all indicators comprising the FRI with relevant measures and thus the user is able to navigate from the FRI page directly to the specific measures.

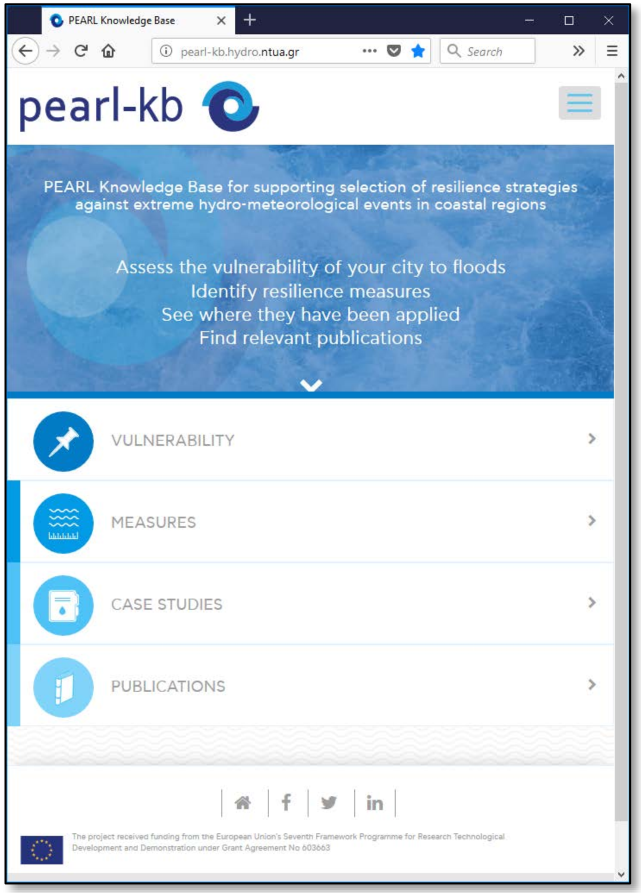
Known **case studies** of the selected resilience measures can be explored next. The user can spot them on a map and review detailed information related to the case study, such as its description, implementation costs, lessons learned etc.

Finally, **publications** and other sources that document the resilience measures of choice or their applications in various coastal regions can be retrieved for further research.

The functionality described above can be accessed in sequence from the homepage of the site. Figure 3 depicts two different views of the homepage of PEARL-KB: a) for devices equipped with large screens (e.g. desktop and wide desktop) and b) for devices with smaller screens (e.g. tablet and smartphone).



a) Homepage as shown on large screen devices



b) Homepage as shown on small screen devices

Figure 3: Two different views of the PEARL-KB homepage

Although this approach may be convenient for many users, other users may prefer a more targeted approach. Using graphical elements such as buttons or menus, the user may navigate directly to specific pages, e.g. resilience measure explorer, case study map, pivot table and publications list. The schema in Figure 4 shows web pages and common navigation paths that may be accessed by the user. They will be described in more detail in this and the following sections.

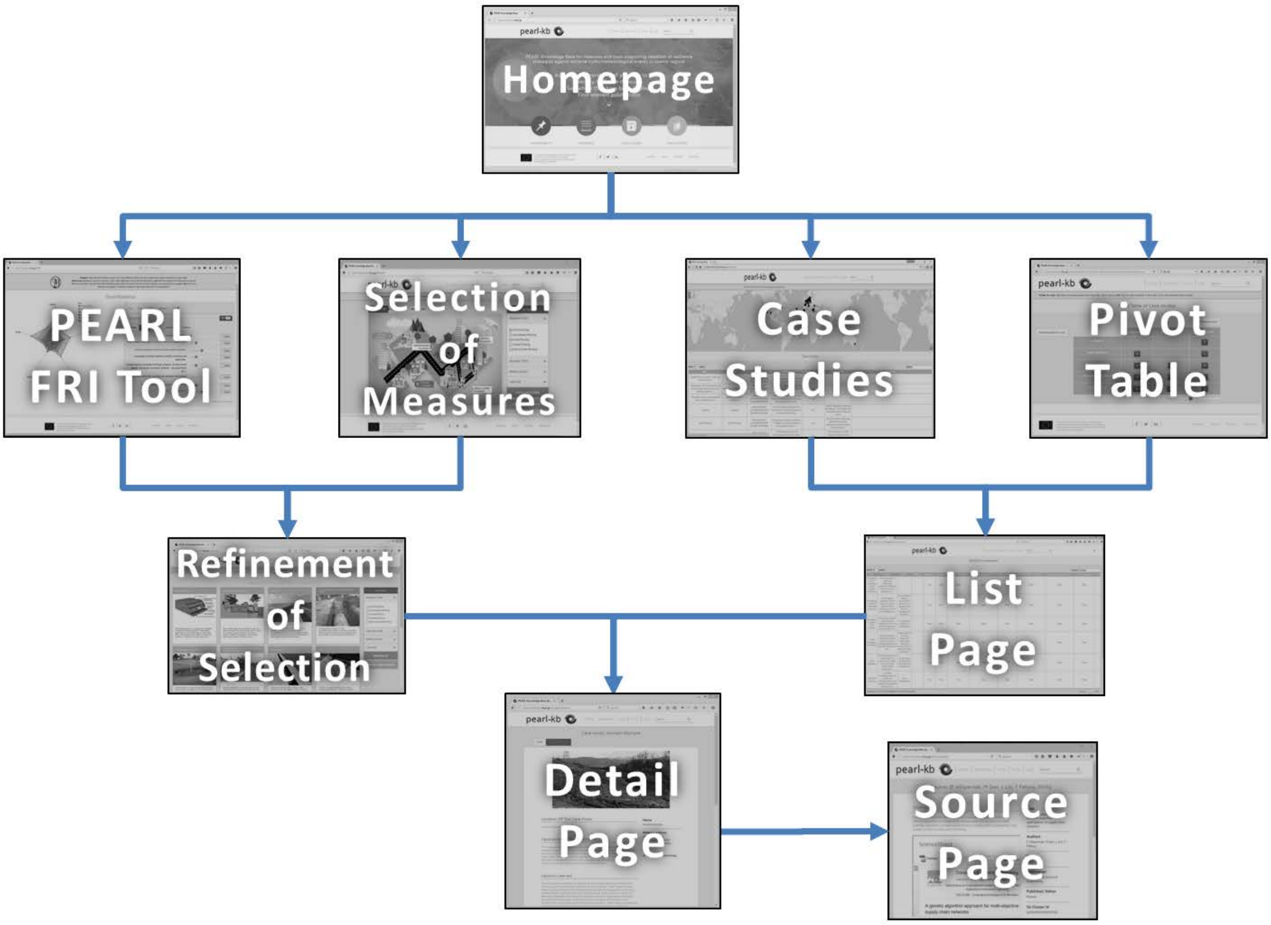


Figure 4: Main navigation paths

3.1 PEARL FRI Tool

The PEARL FRI Tool will help the user to assess the resilience of a city in five different dimensions, visualize the results and find appropriate measures. The FRI indicator is based on the framework developed by [Batica J. et. al., 2013], which assesses resilience related to flood risk management by employing five dimensions in order to evaluate the level of disturbance and the ability to cope with various issues during and after a flood event. The methodology was initially developed within the CORFU project [CORFU, 2017] and has been revised and enhanced within the PEARL project [Karavokiros et. al., 2016].

By using the tool, users are able to estimate the resilience of a city for a specific flood event (or flood type event) in five dimensions, visualize the results in a spider diagram and compare them with other flood (type) events of the same city as shown in Figure 5 or use it for knowledge

exchange among different local stakeholders engaged in flood management procedures. The following features are supported by the system:

(1) Assess the resilience of a city by selecting one-by-one the dimensions from which the FRI consists. Each dimension is associated with a number of indicators listed under the FRI menu. The size of the font of each indicator is proportional to its weight, as it has been estimated by experts for a typical pluvial or fluvial flooding. Next to the name of each indicator, a slider can be moved to indicate how well the city performs in the respective field. Moving the slider to the one or to the other direction changes the estimated value of the indicator, which affects the performance in the respective dimension and the overall FRI.
(2) Observe immediately the results of an action on the spider diagram and the FRI display.
(3) Inspect how other cities, which are stored in the database, have scored in five dimensions and in each one of the indicators. To do so one has to select them from the main FRI menu under the selection `Sites` or click on their name in the legend of the spider diagram.
(4) Once vulnerabilities have been identified, search for measures that might improve the city's resilience. By clicking on the name of an indicator users are navigated to a list of measures influencing this specific indicator.

The weightings of the indicators have been assessed by experts for typical fluvial and pluvial floods. However, some of the weighting factors might have quite a different value for other types of floods such as coastal floods originating from storm surges. Moreover, the importance of some indicators may vary from one site to another and thus the default weights suggested by the PEARL FRI Tool may not always represent the local circumstances. Therefore, it is possible to disable certain indicators by selecting `Settings/Custom FRI` from the main menu. After that a button appears next to each slider enabling the user to customize the overall FRI indicator. Taking into account only the active indicators, the FRI is calculated by applying the following equations:

$$FRI = \frac{\sum_{j=1}^{5} WD_j \times FRID_j}{\sum_{j=1}^{5} WD_j}$$

$$FRID_j = \frac{\sum_{i=1}^{n_j} W_{ij} \times s_{ij}}{\sum_{i=1}^{n_j} W_{ij}}$$

where:

$FRID_j$ is the calculated Flood Resilience Index for a dimension j

WD_j the weight for dimension j

and W_{ij} the weight for indicator i and dimension j

s_{ij} the score indicating how well a city performs in the field covered by a specific indicator.

n_j the number of indicators in dimension j

The PEARL FRI Tool has been translated into the Greek language, accessible from the menu under `Language/Greek(Ελληνικά)`, in order for the stakeholders of the Rethymnon City Case Study, participating in the local Learning and Action Alliance (LAA), to better understand the Tool and provide feedback during the development process.

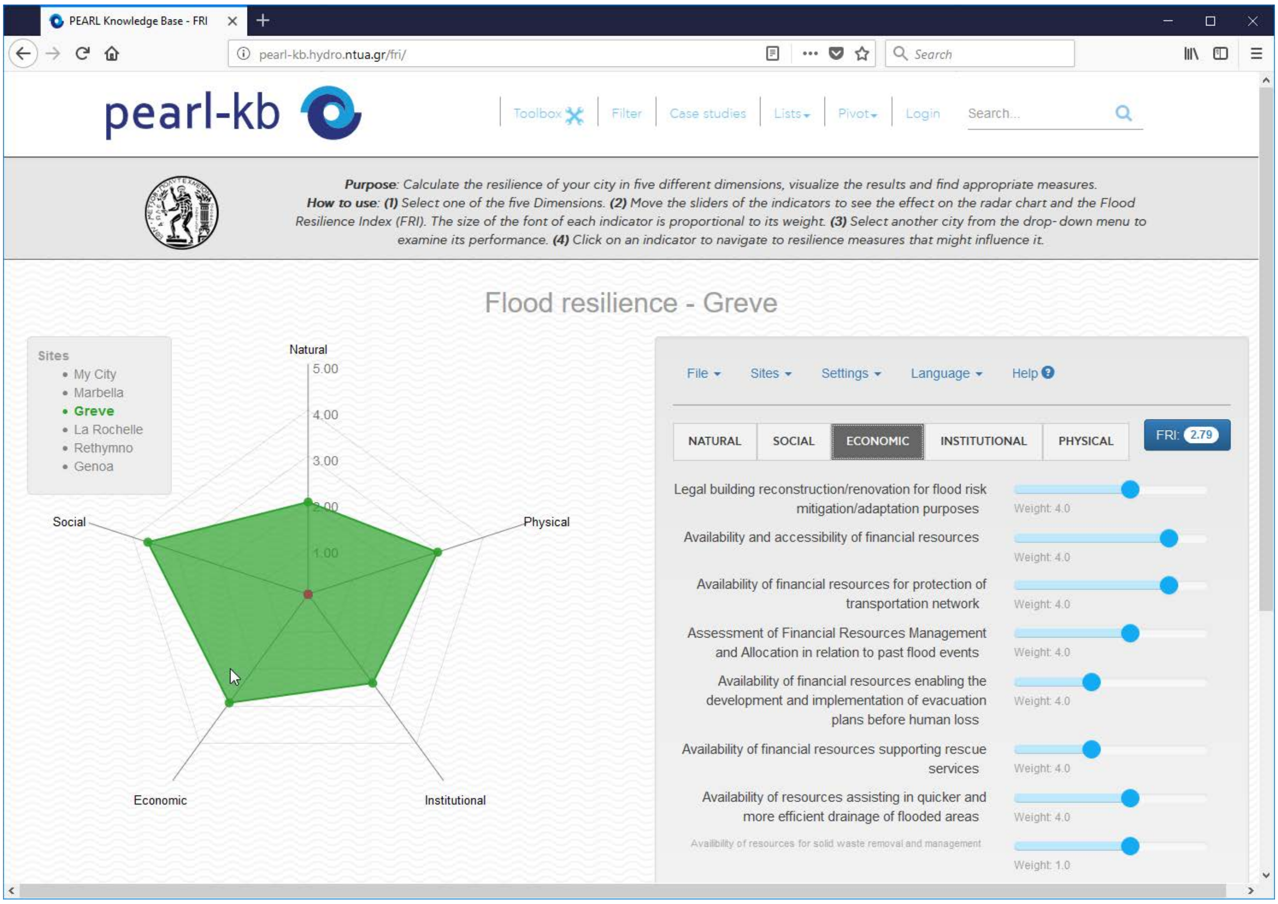


Figure 5: The PEARL FRI Tool

3.2 Exploring resilience measures

A number of resilience measures have been identified by project experts and stored in the PEARL KB. They originate from various sources, such as related projects (e.g. NWRM, PREPARED) and contributions from PEARL project partners. A full list of measures is provided in Annex 3 - List of Resilience Measures.

There are several ways for the user to explore the Knowledge Base for resilience measure and identify the ones relevant for a specific purpose. Next to the possibility to retrieve a list of measures influencing a specific FRI indicator, as shown in previous section, the following main options are offered:

- Use the interactive filter page to search based on criteria in specific categories (section 3.2.1)
- List all measures in a tabular form and narrow down the search based on keywords (section 3.4)
- Use pivot tables to track down those measures which fulfil selected criteria (section 3.5)
- Perform full text search on the descriptive fields of the Knowledge Base and select from the resulting page the `Resilience measures` tab (section 3.7)
- Cross links to related measures from the detail page of another item, e.g. case study or publication (section 3.6).

3.2.1 Filters

When selecting `Measures` from the homepage or `Filter` from any other page, the user is navigated to the resilience measure filter page consisting of four interactive tabs representing the following data categories:

- **Problem Types** can be selected from a) Pluvial flooding, b) Groundwater flooding, c) Fluvial flooding d) Coastal flooding and e) Drain and sewer flooding (Figure 6).
- **Measure Types** can be selected from a) Engineering, b) Environmental, and c) Operational measures (Figure 7).
- **Spatial Scales** can be selected from a) River basin,b) Street, c) City, d) Neighbourhood and e) Building (Figure 8).
- **Land Uses** can be selected from the following types: a) Urban, b) Suburban, c) Rural, d) Coastal e) Industrial and f) Park (Figure 9).

The same filtering criteria can be selected from the checkboxes in the drop-down lists appearing next to the graphical representation (see Figure 10).

Figure 6: Problem type filter

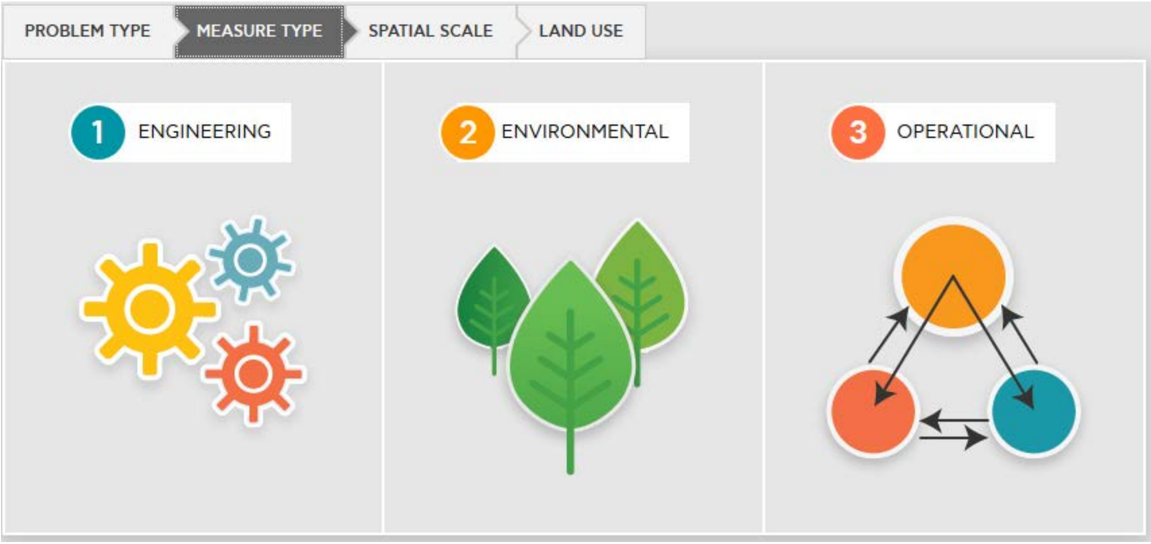


Figure 7: Measure type filter

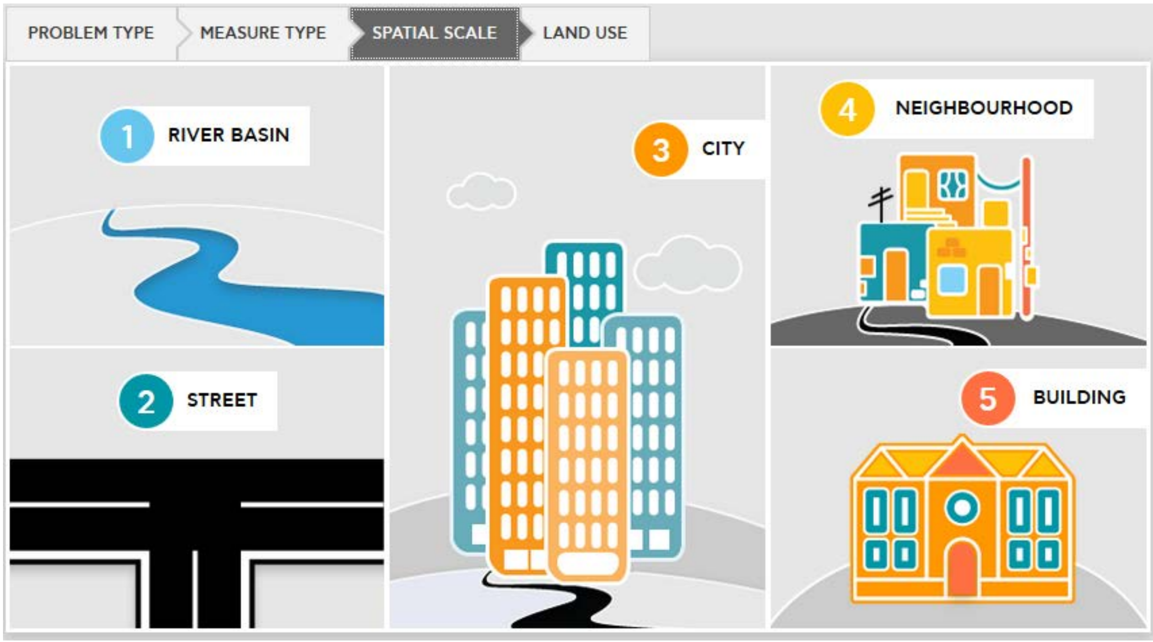


Figure 8: Spatial scale filter

Figure 9: Land use filter

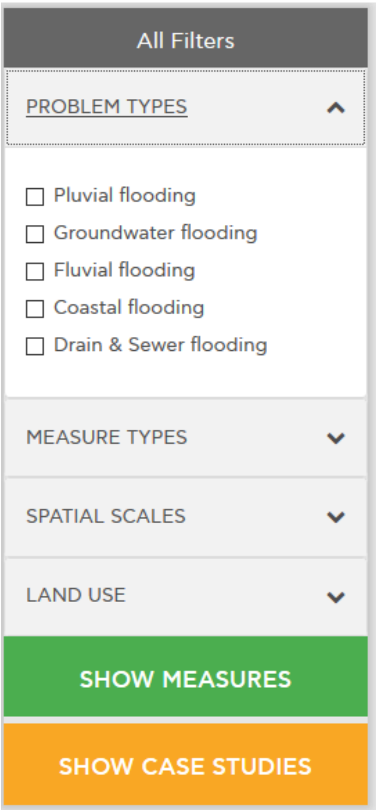


Figure 10: Mull-down menu of criteria for selecting resilience measures

The results of a query with the selected filtering criteria are shown by pressing with the mouse on the button SHOW MEASURES. The query is executed as logical conjunction of the selected criteria. The title, a representative picture and the initial sentences of the description of the first twelve resulting measures appear as depicted in Figure 11. In case more measures fulfil the criteria, they are split up in pages. The layout of the page follows the responsive web design principles, i.e. the results appear in one, two, three or four columns, depending on the display analysis of the user's device.

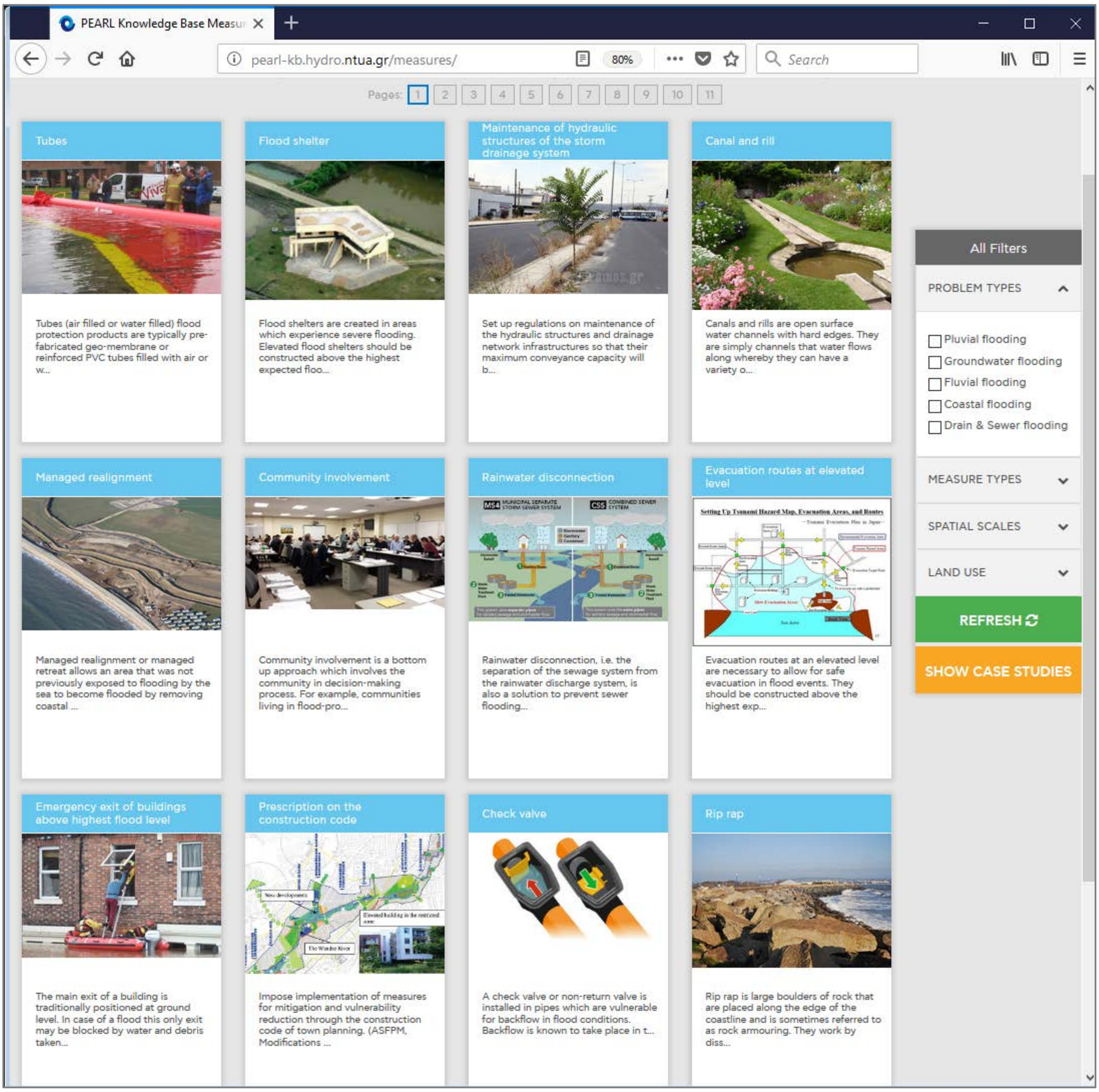


Figure 11: Results of a search for resilience measures

The user may continue refining the search using the drop-down lists and then pressing the REFRESH button or proceed to the detail page of a measure (see section 3.6) by clicking on its image.

3.3 Case studies

Same as for the various types of resilience measures, their applications, i.e. case studies all over the world stored in the PEARL KB can be explored in one of the following ways:

- Use the interactive filter page to search based on criteria in specific categories (section 3.2.1)
- List all case studies in a tabular form and narrow down the search based on keywords (section 3.4)
- Use pivot tables to track down those case studies which fulfil selected criteria (section 3.5)
- Perform full text search on the descriptive fields of the Knowledge Base and select from the resulting page the `Case studies` tab (section 3.7)
- Cross links to related case studies from the detail page of another item, e.g. a measure or publication (section 3.6).

The first three from the above options navigate the user to the landing page shown in Figure 12. It is divided into two parts:

The upper part of the page shows a map on which the locations of the case studies selected from the previous process, are depicted. They are represented by small cycles. By clicking with the mouse on a cycle, the title of the case study appears as a hyperlink that navigates to the related detail page. On the lower part of the page, basic data of the same case studies are listed in tabular form. By clicking with the mouse on a row, the user is navigated to the respective case study.

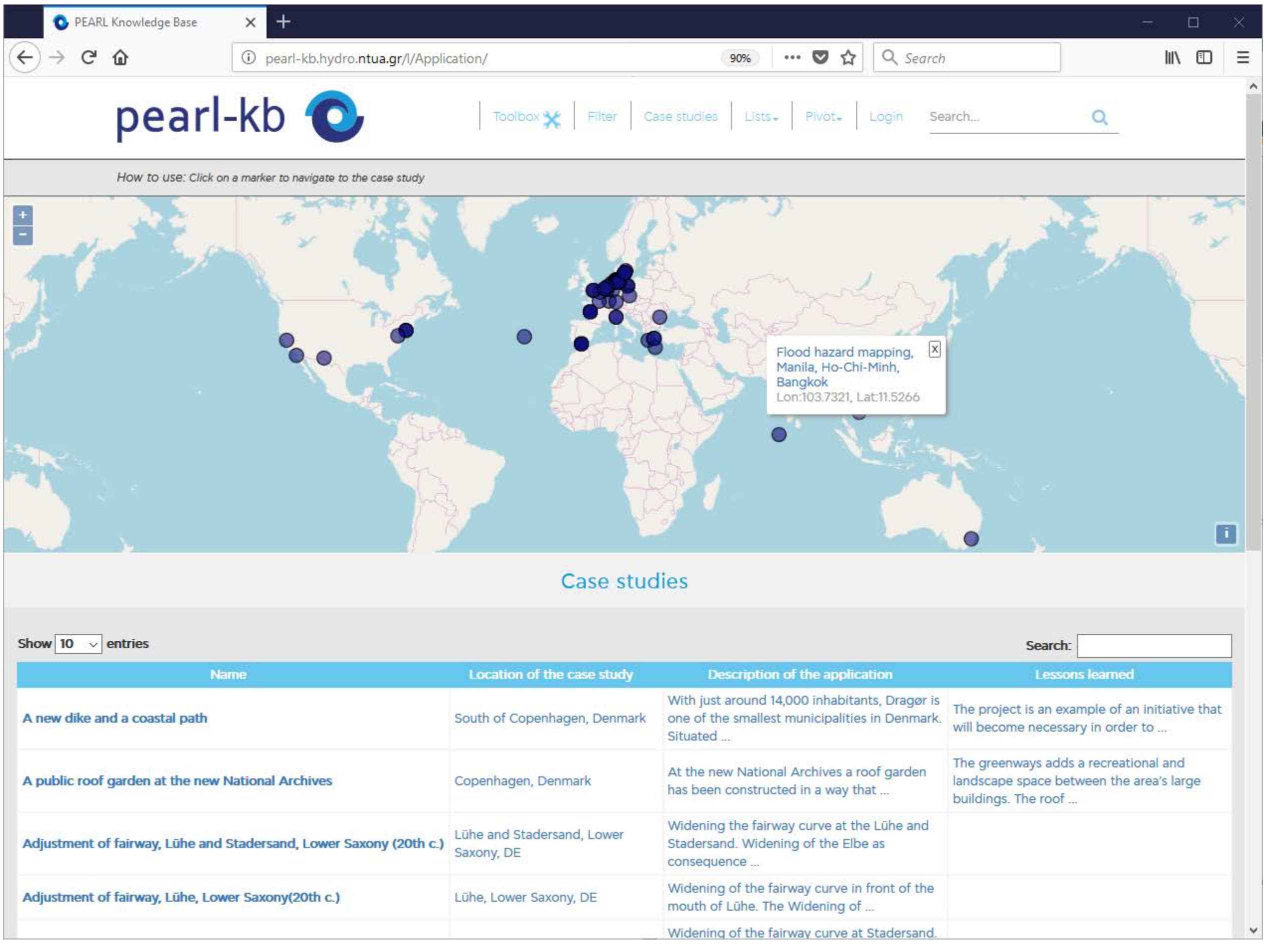
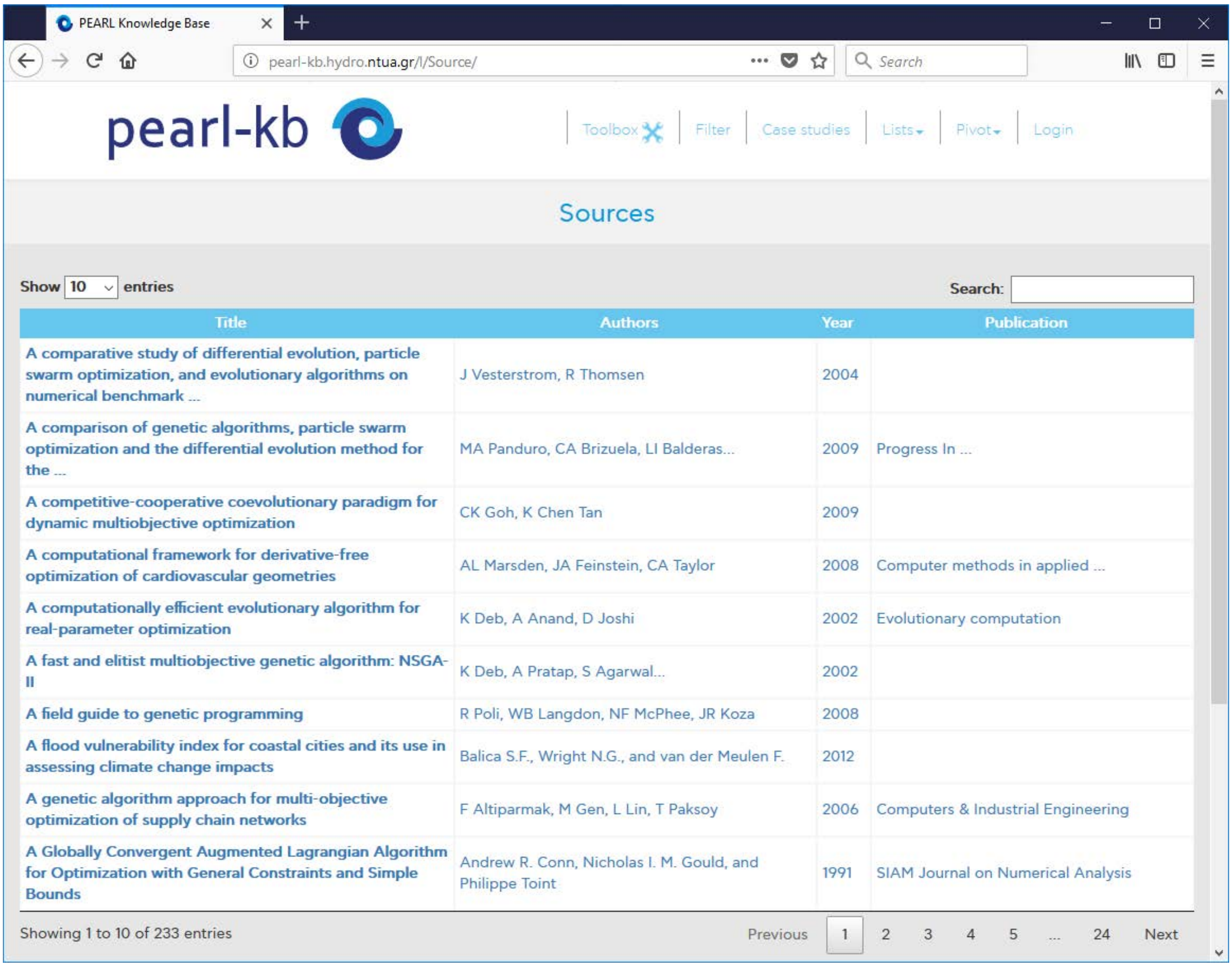


Figure 12: Case studies landing page

A full list of case studies stored in the PEARL KB is provided in Annex 4 – List of Case Studies.

3.4 Lists

In the previous section it has been described how case studies are presented in form of lists. Other data categories can be listed in the same way. Each item of a data category is represented by one row, in which basic characteristics of the item are provided. In case of a large number of items, the results are presented in several pages. The number of items (entities) shown in each page can be defined in the pull down menu `Show entities`. One can narrow down the list by specifying keywords in the field `Search` on the top right corner of the table. By clicking with the mouse on a row the user is navigated to the detail page of the respective item. Figure 13 depicts the list page of sources (publications) as an example.



Title	Authors	Year	Publication
A comparative study of differential evolution, particle swarm optimization, and evolutionary algorithms on numerical benchmark ...	J Vesterstrom, R Thomsen	2004	
A comparison of genetic algorithms, particle swarm optimization and the differential evolution method for the ...	MA Panduro, CA Brizuela, LI Balderas...	2009	Progress In ...
A competitive-cooperative coevolutionary paradigm for dynamic multiobjective optimization	CK Goh, K Chen Tan	2009	
A computational framework for derivative-free optimization of cardiovascular geometries	AL Marsden, JA Feinstein, CA Taylor	2008	Computer methods in applied ...
A computationally efficient evolutionary algorithm for real-parameter optimization	K Deb, A Anand, D Joshi	2002	Evolutionary computation
A fast and elitist multiobjective genetic algorithm: NSGA-II	K Deb, A Pratap, S Agarwal...	2002	
A field guide to genetic programming	R Poli, WB Langdon, NF McPhee, JR Koza	2008	
A flood vulnerability index for coastal cities and its use in assessing climate change impacts	Balica S.F., Wright N.G., and van der Meulen F.	2012	
A genetic algorithm approach for multi-objective optimization of supply chain networks	F Altiparmak, M Gen, L Lin, T Paksoy	2006	Computers & Industrial Engineering
A Globally Convergent Augmented Lagrangian Algorithm for Optimization with General Constraints and Simple Bounds	Andrew R. Conn, Nicholas I. M. Gould, and Philippe Toint	1991	SIAM Journal on Numerical Analysis

Figure 13: Example of a list page showing sources (publications)

3.5 Pivot tables

An alternative way to retrieve the desired information stored in the PEARL KB is offered through the pivot table. A user can navigate to the desired pivot table page by selecting it from the main menu.

A pivot table is a generic tool which summarizes information from several other tables and can be applied on any class of the KB. By selecting a class from the pivot menu a pivot table of this class appears. Each of the two dimensions of the class table is associated with a property of the class

selected from the pull-down menus. Columns and rows represent the values of lookup tables associated with the selected properties. In each cell of the pivot table a number is displayed representing the stored items that match both property values specified by the line and the column of the cell. By clicking on a cell the user is navigated to the list page (see section 3.4) providing detailed information on these items. The example in Figure 14 gives the number of case studies having implementation costs at a certain range (rows) and at the same time applying measures that are of specific type (columns). This example demonstrates also the ability of the pivot table to collect information that span across several tables. *Measure types* is actually a property of the class *Measures* which is related to the class *Case studies*. By specifying the scope of the pivot table the user can determine how far from the pivot class in the Knowledge Base the query should reach. Scope 0 means that only the properties directly associated with the pivot class should be available for selection from the pull-down menus, while scope n means that the selection list will be expanded to include properties of related classes that span across n relations from the pivot class.

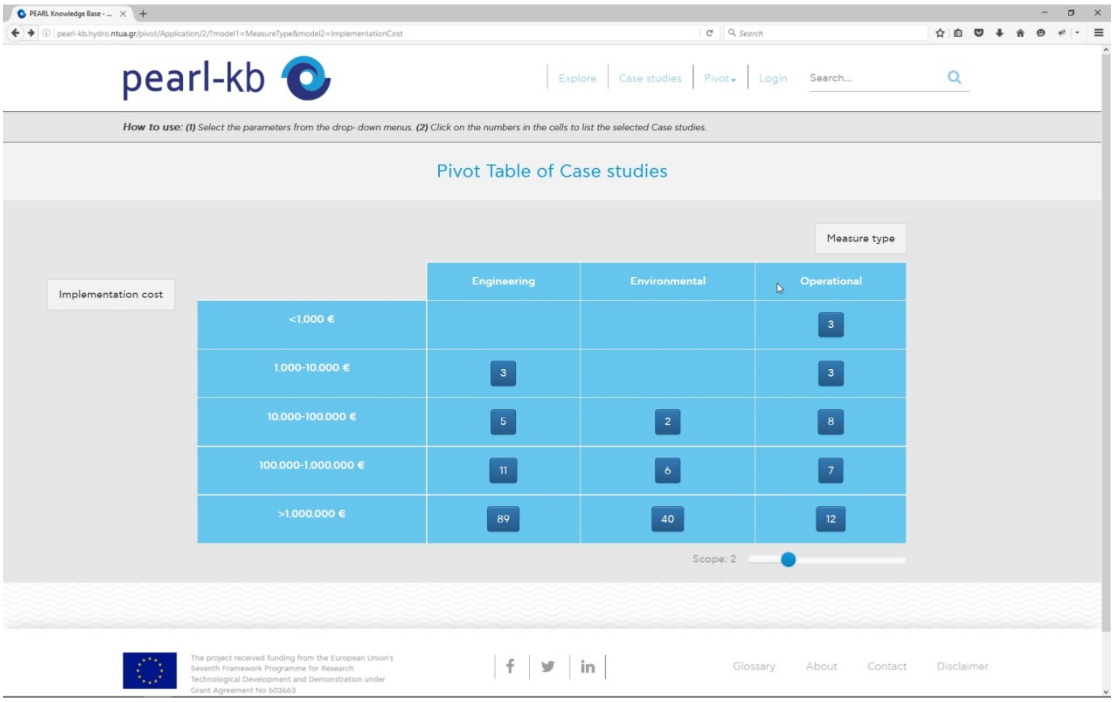


Figure 14: Example of a pivot table showing the number of case studies that meet certain criteria

3.6 Detail pages

A detail page summarizes all data of a specific item. These may be numbers, boolean variables, textual information, URLs, geographic data, illustrations and relationships to other items. The page is then rendered according to the identified information (see Figure 6). In case of georeferenced items (e.g. case studies) and provided such information is available, a map appears on top of the page showing its location. Illustrations appear in another tab on top of the page.

This page is often the endpoint of a search for an item from a specific data category. However, cross links to related items are listed and the user can continue his search by navigating directly to the detail pages of the related items. A tooltip explaining the relationship in a human readable sentence appears by hovering the mouse over the hypertext.

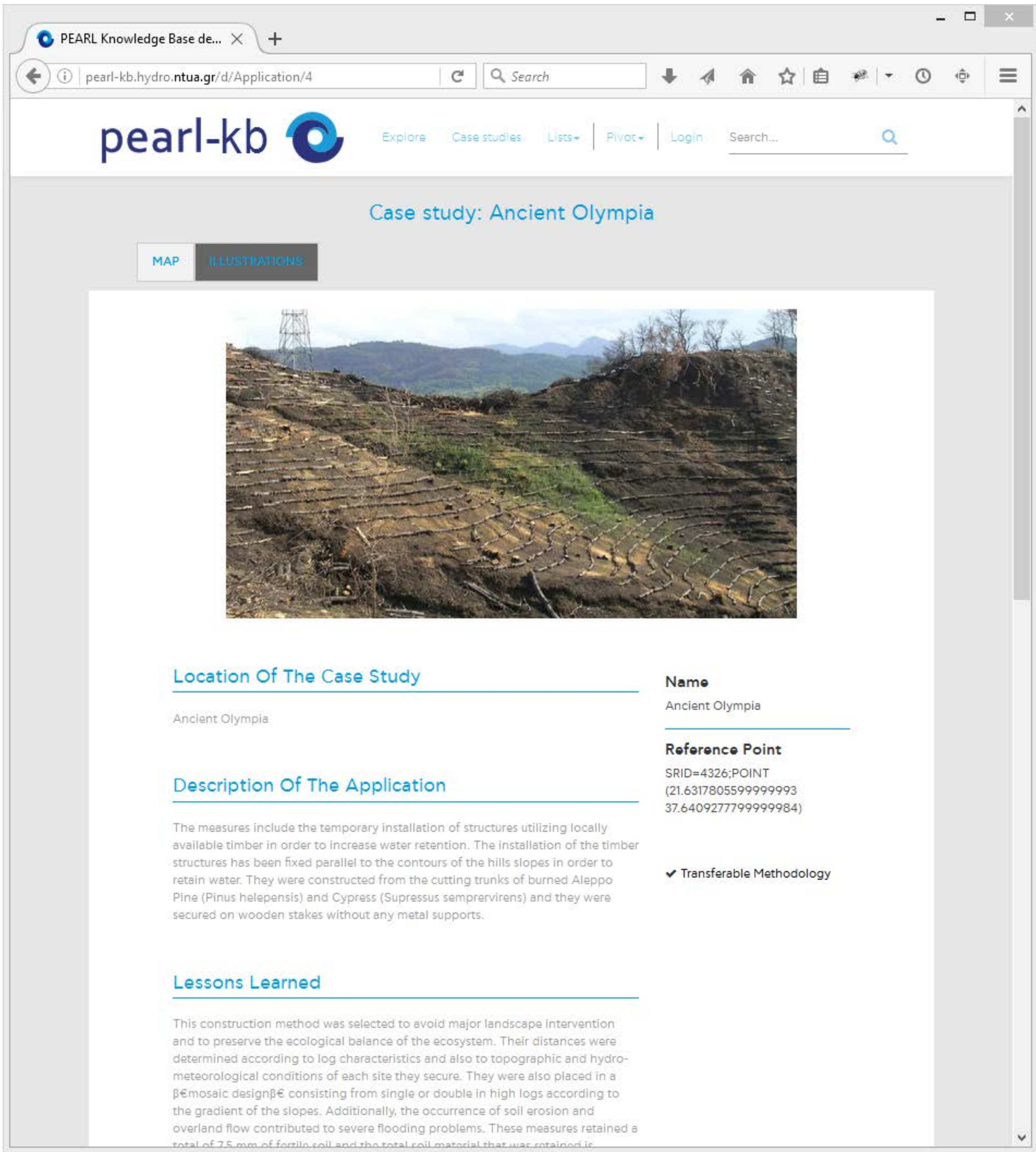


Figure 15. Example of a detail page

3.7 Full text search

An alternative way to find the desired information is full text search to all kinds of stored textual data stored in the PEARL KB. This includes names of entities, classes, descriptions, etc. The search algorithm is based on Levenshtein Distance [Levenshtein, 1966] for approximate string matching, i.e. finding strings within a longer text that match a given keyword approximately. The results are presented as an excerpt of the text in which the given keyword has been encountered, along with the names of the relevant item and property including a link to the item's detail page (Figure 16).

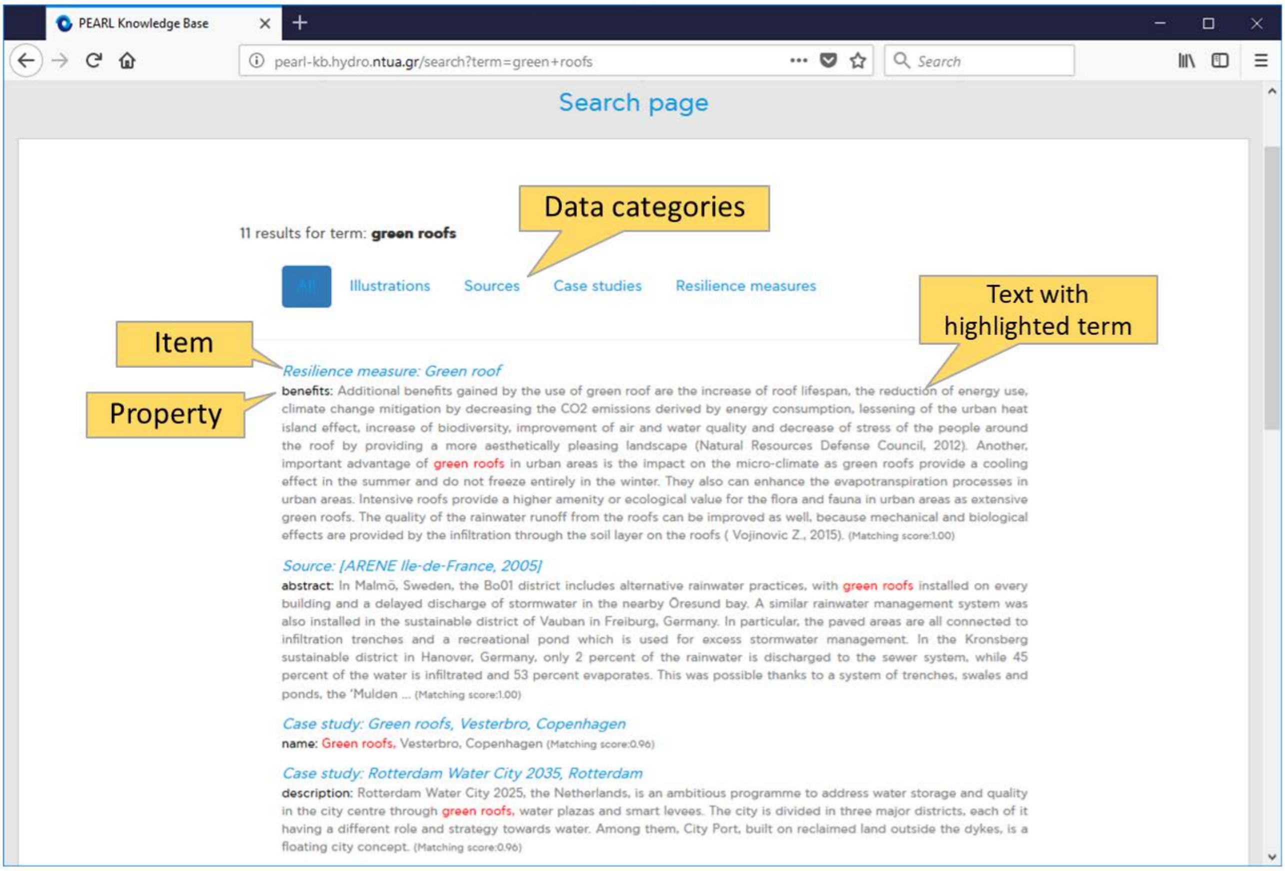


Figure 16: Results from the full text search

4 Administrator’s guide

PEARL KB enables authorized users to submit data and control the content of the Knowledge Base through the administration pages. In order for a user to access the administrator pages he must authenticate himself with valid credentials (username and password) provided by the administrators of PEARL KB. They can be contacted through the following email: **pearl-kb@hydro.ntua.gr**. Only registered users are permitted to submit content to the PEARL KB.

4.1 User roles

Registered users are assigned to one or more roles giving them certain privileges and capabilities. PEARL KB recognizes the following user roles:

Administrators: Administrators have almost unlimited access to the Knowledge Base. They are able to modify all content, but their most significant task is the user management, i.e. they are authorized to add and remove users from the user list as well as to assign and modify user roles.

Data providers: Data providers have privileges related with the administration of specific content. More specifically they are able to edit existing and add new records from the following data categories:

(a) Resilience measures and their synonyms,

(b) Applications of resilience measures, i.e. mainly cases studies,

(c) Illustrations, showing case study areas or representative illustrations of a resilience measure,

(d) Publications related with resilience measures or case studies and

(e) Projects

For security reasons data providers are not allowed to delete any records.

The following description of the administration pages is adapted to the data provider role.

4.2 User authentication

4.2.1 *Login form*

Users can login into the system by selecting `Login` from the main menu (Figure 17).

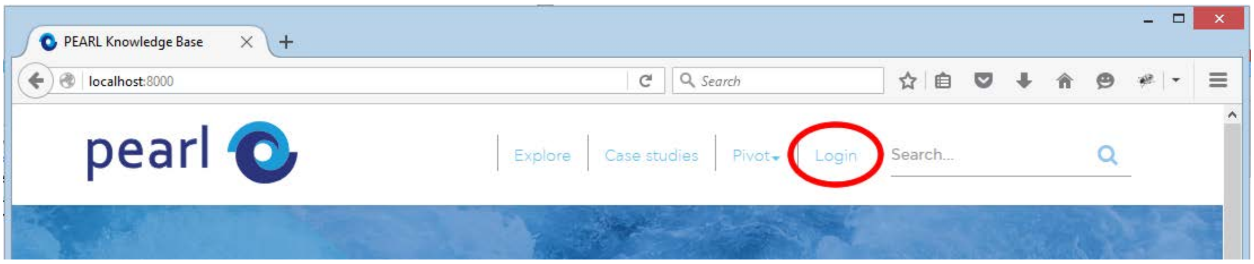


Figure 17: Selection of the login page from the main menu

After that, the user authentication form appears (Figure 18).

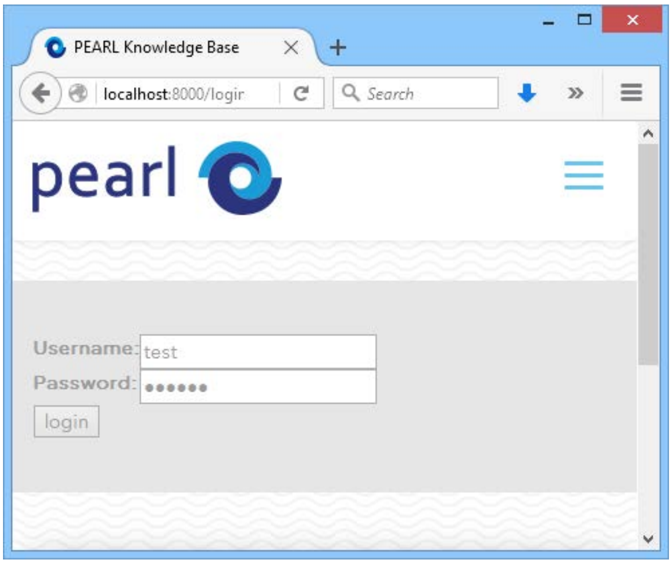


Figure 18: User authentication form

Right after a successful login the main menu of PEARL KB is enhanced with additional selections (Figure 19). They refer to the following options:

`Admin/Logout`	Leave the privileged user mode (see section 4.2.2).
`Admin/Change password`	Change the user password (see section 4.2.3).
`Admin/Add/Resilience measure`	Navigate to the page for adding a new resilience measure (see section 4.3.2)
`Admin/Add/Synonym for RM`	Navigate to the page for adding a new synonym for a known resilience measure (see section 4.3.3)
`Admin/Add/Case study`	Navigate to the page for adding a new case study (see section 4.3.4)
`Admin/Add/Illustration`	Navigate to the page for adding a new illustration related to a case study or a resilience measure (see section 4.3.5)
`Admin/Add/Publication`	Navigate to the page for adding a new publication (see section 4.3.6)
`Admin/Add/Projects`	Navigate to the page for adding a new project from which knowledge is harvested (see section 4.3.7)
`Admin/Modify/...`	Navigate to the page for modifying an existing record from the above categories (see section 4.4)

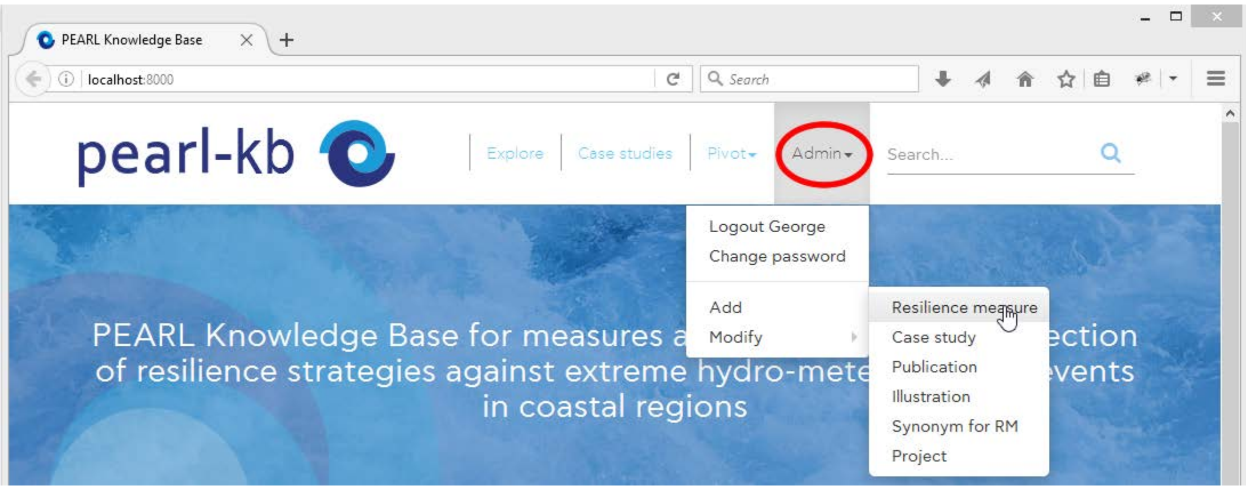


Figure 19: Additional options available to authorized users

4.2.2 Logout

Once a user has been successfully authenticated to the system he has entered the privileged user mode. He can leave this mode by selecting `Admin/Logout` from the main menu. After that the website returns to the normal mode and appearance again.

4.2.3 Password change

By selecting `Admin/Change password` from the main menu, users are able to change their existing password (Figure 20).

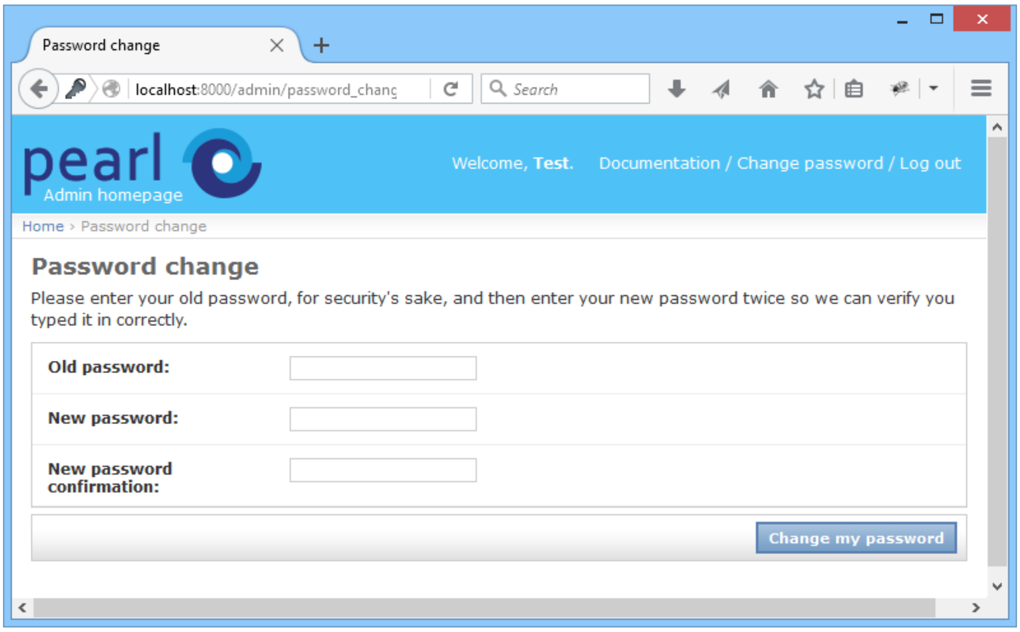


Figure 20: Change password form

Users are advised to change their initial password provided by the administrator with another non-trivial one.

4.3 Adding content

To add new content, an authorized user must authenticate himself by logging in to the system (see section 4.2). After that, he may select from the PEARL KB main menu `Admin/Add` to navigate to one of the detail pages (see the following subsections).

4.3.1 Detail pages

The functionality described in this section is common to all following detail page sections.

A detail page contains a form with a number of fields consisting of:

- The title of the field
- The graphical element for data entry (e.g. text field, drop-down menu, list etc.)
- A hint appearing below the graphical element, describing the requested information or how to enter data.

Some field titles, appearing in **bold**, indicate that this field is mandatory, i.e. the system will not allow the user to upload the record unless he has provided data for these fields. Some pages may also have additional conditional mandatory fields. In multiple choice fields, hold down the "Control" key, or the "Command" key on a Mac, to select more than one term or to unselect a previously selected term. In any case one should complete each form as far as possible and avoid data gaps.

Next to some fields the Plus icon ( ) and the Edit icon ( ) may appear. This means that the user is allowed to create a new element of this category or edit the selected one before submitting the form.

By clicking on the button `History`, appearing on the upper-right corner of the screen, the user can list all modifications that have been done to this record so far.

At the bottom of the screen one can select from the following options:

Delete	Delete the record currently on screen
Save and add another	Save the current record to the Knowledge Base and clear all fields to add another one.
Save and continue editing	Save the current record to the Knowledge Base and continue editing on the same one.
Save	Save the current record to the Knowledge Base and navigate to the main admin menu.

Upon saving a record, a number of validation checks apply. Typically, they include mandatory field checks and data type checks (e.g. integer or real number, text etc.). See Annex 1 – Validation rules for additional validation checks per data category. Data entry errors are pointed out and the user is requested to correct the specific fields and resubmit the record (Figure 21). A full list of all attributes per data category is given in Annex 2 – Description of attributes.

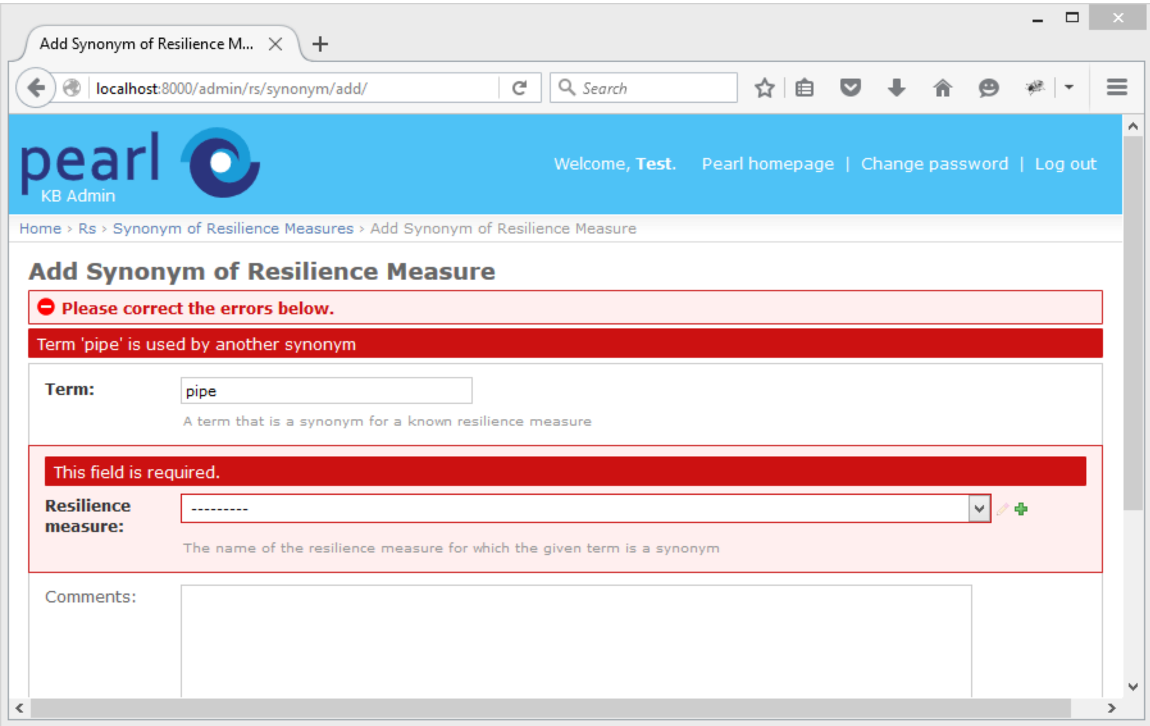


Figure 21: Example of error messages

4.3.2 Resilience measures

This data category refers to known measures or activities, including processes, which aim at avoiding, reducing, remedying or compensating for adverse impacts of floods. Items of this data class are not applications of measures (i.e. case studies), but rather categories of measures describing an engineering, environmental or operational methodology or activity.

A new measure can be added by selecting `Admin/Add/Resilience measure` from the main menu.

⚠	Before adding new measures, please review the existing measures stored in the PEARL KB (e.g. shown from the menu `Explore/Show Measures`). The one you want to add might be already stored in the Knowledge Base, possibly with another name.
	Often a measure is just a variation of a more general one which is already stored in the PEARL KB. You may add the new measure and establish the parent-child relationship at the same time: A parent-child relationship, in terms of supercategory-subcategory, between resilience measures can be established by selecting from the field `Parent` the supercategory of the current measure.

Representative pictures of resilience measures can be uploaded from the illustration detail page (see section 4.3.5). Publications related to resilience measures can be uploaded from the source detail page (see section 4.3.6).

4.3.3 *Synonyms for resilience measures*

Resilience measures and strategies are often called with different names. The PEARL-KB should be aware of synonyms used for a reported resilience measure. A synonym for a reported resilience measure can be added by logging into the system and selecting from the main menu `Admin/Add/Synonym for RM`. The synonym detail page appears (see Figure 22).

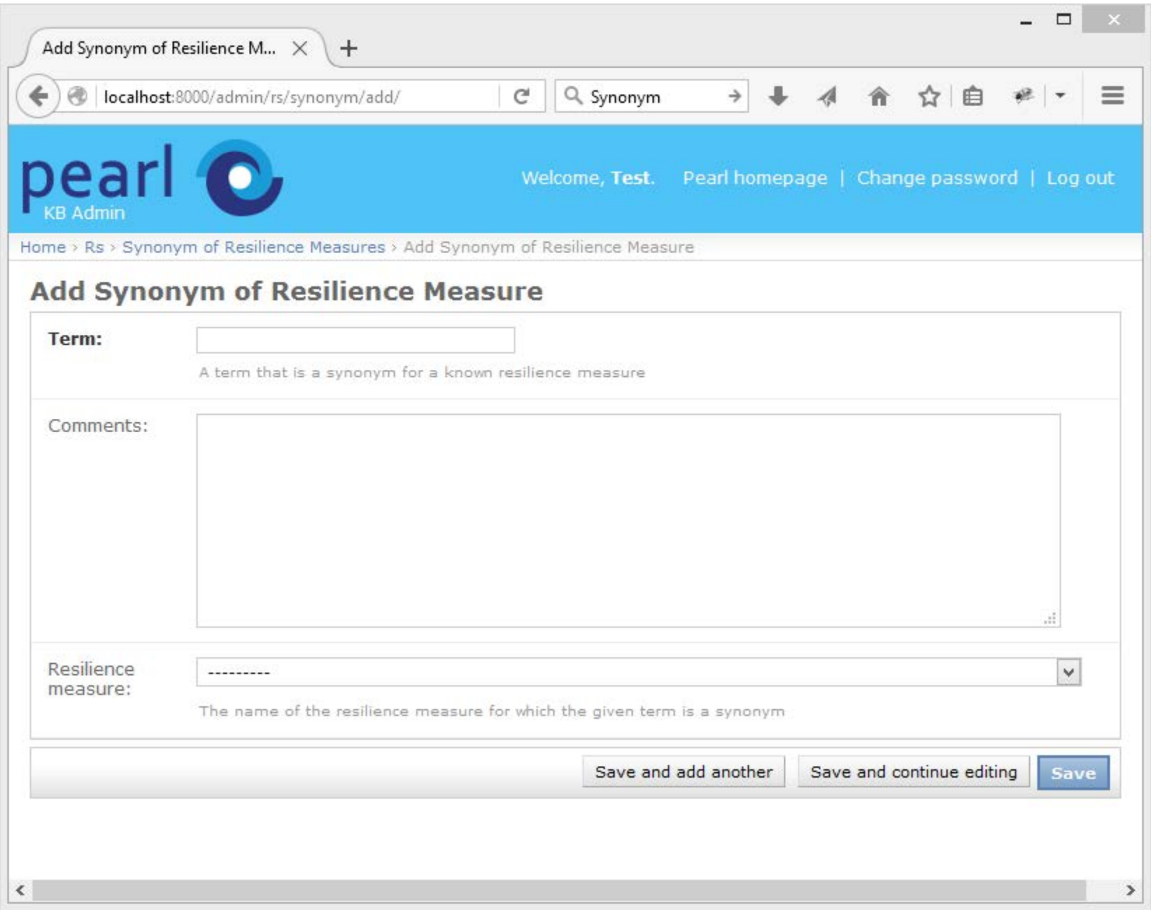


Figure 22: Synonym detail page

⚠	Sometimes a specific resilience measure is not exactly identical with another already reported measure and thus their names are not synonyms but the new measure defines a subcategory of the stored one. In this case a new resilience measure has to be defined (see section 4.3.2), in which the parent measure (supercategory) is specified.

4.3.4 *Applications of resilience measures (cases studies)*

Applications of resilience measures refer to real case studies, to modelled/simulated case studies or even to prototypes/lab physical models.

To add a new case study, a user having data provider privileges must log in to the system (see section 4.2). After that he can choose from the PEARL KB main menu `Add/Case study`. He is then navigated to an empty detail page template which he can fill-in with the relevant data (see Figure 23).

The name of the case study should be carefully selected. It should be small and comprehensive, should have a reference to a region and should not be identical with other case studies already stored in the KB.

In order to pinpoint the location of the case study on the map the following steps have to be taken:

1. Select the Edit button on the upper-right corner of the map
2. Click with the mouse on the map to pinpoint the location of the case study

The selection can be undone by clicking on the text `Delete all Features` at the bottom of the map.

Pictures of the case study can be uploaded from the illustrations detail page (see section 4.3.5). Publications related to the case study can be uploaded from the sources detail page (see section 4.3.6).

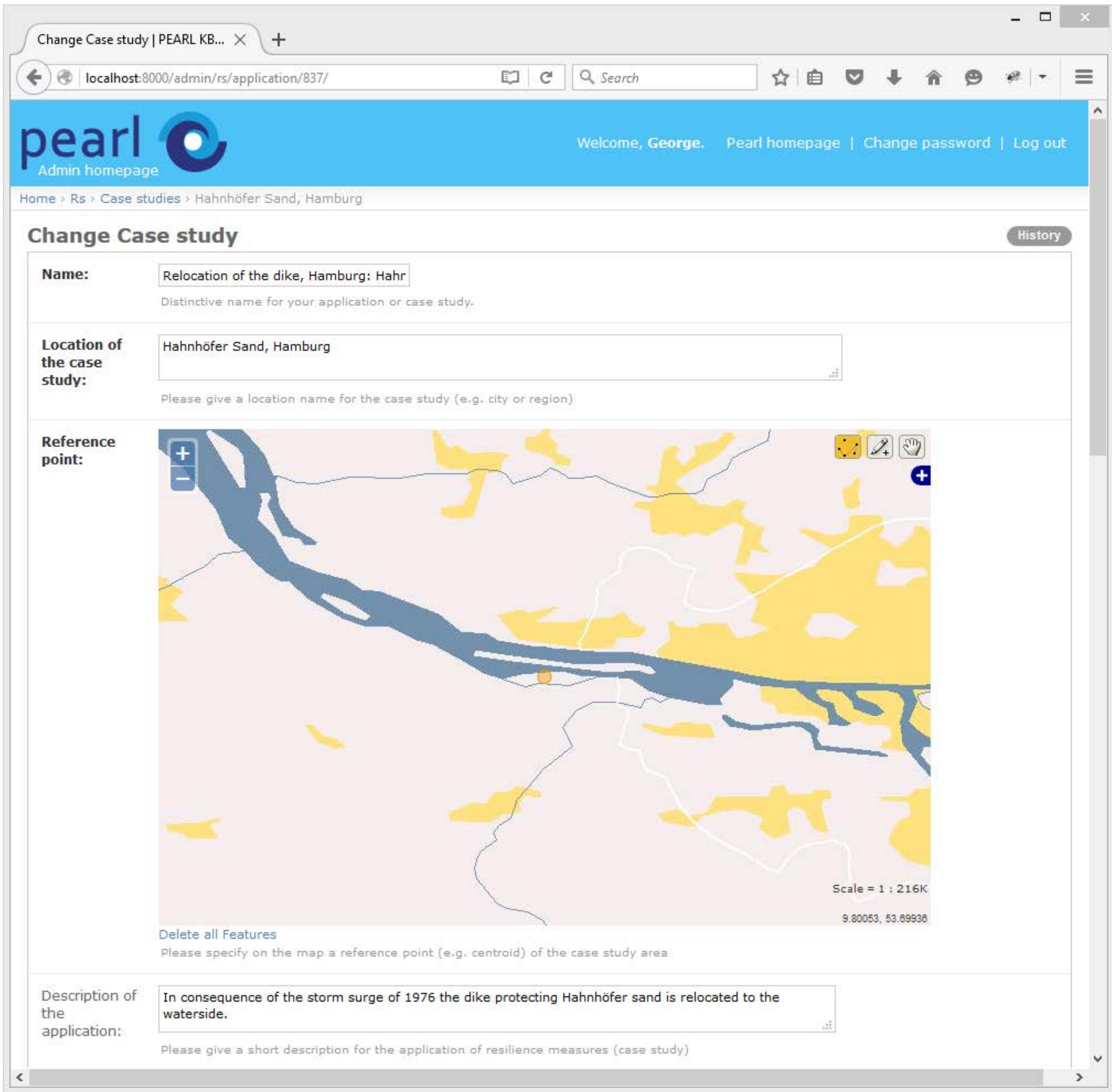


Figure 23: Case study detail page

4.3.5 *Illustrations*

The illustration detail page (Figure 24) refers to metadata of an illustration showing either a case study site or a reference picture of a resilience measure or both. The illustration file itself can be uploaded by clicking on the button `Browse…` from the filed `Image`. The selection of a related application or resilience measure is mandatory, i.e. at least one item from the aforementioned categories must be selected.

Illustrations should have landscape orientation and their file format must be supported by web browsers (e.g. png, jpg). They should have high resolution and their size should not exceed 1MB.

In case the related case study or resilience measure record has not been uploaded yet, one can add it by clicking on the Plus icon (✚) next to the drop-down menu. A selected case study or resilience measure can be edited by clicking on the Edit icon (✎).

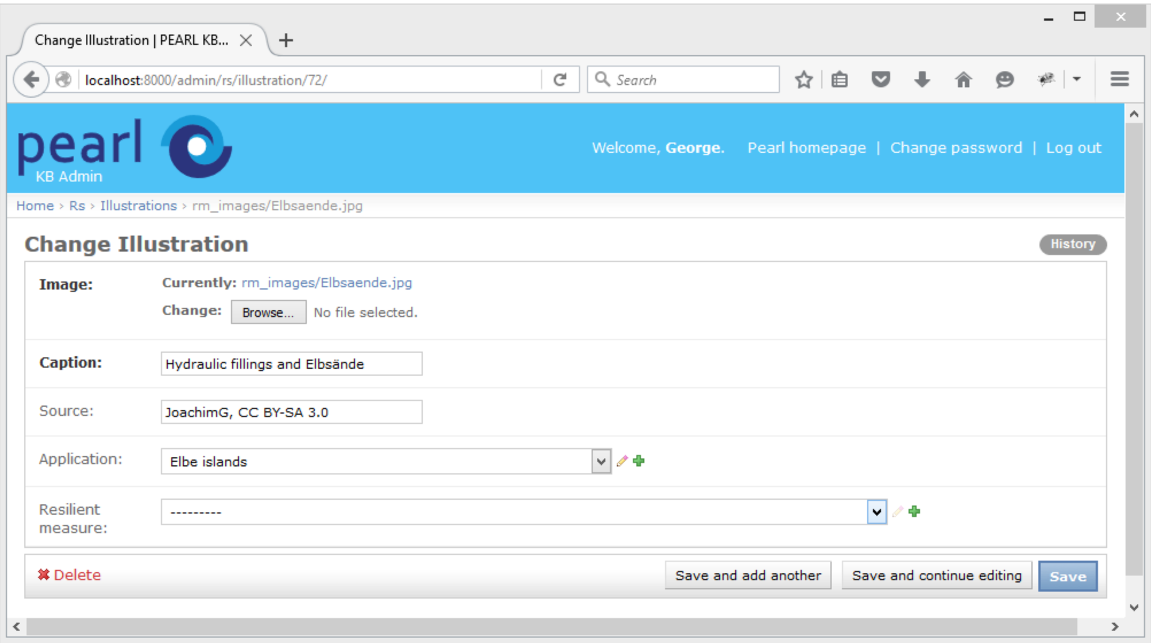


Figure 24: Illustration detail page

4.3.6 *Sources*

The source detail page refers to a publication or source related to one or many resilience measures or/and case studies (Figure 25). Apart from the fields appearing in bold, some other fields might be also mandatory depending on the selected source type (conditional mandatory fields). If for example the source type `Web resource` is selected, it is expected that a valid URL is specified, a field which otherwise would be optional.

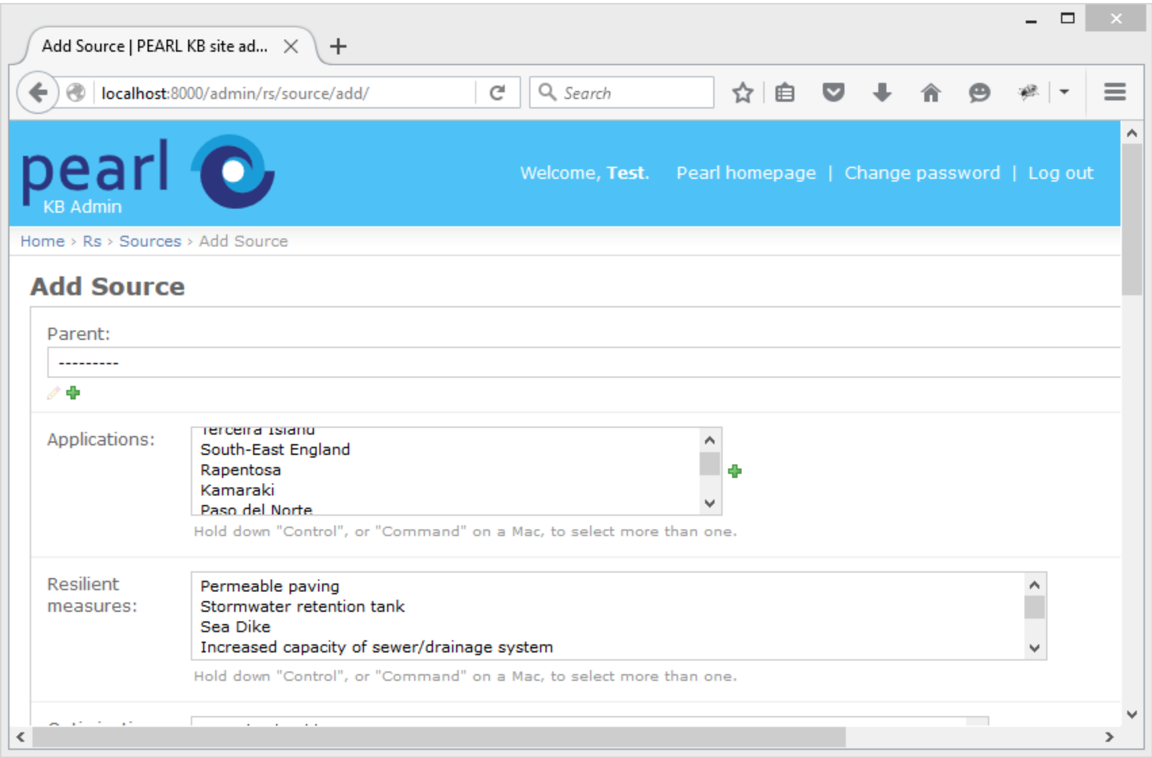


Figure 25: Source (publication) detail page

4.3.7 *Projects supporting PEARL KB with knowledge*

Online repositories may be harvested to populate PEARL KB with data. Through the Project detail page one can add information about the project from which the data originate (Figure 26). The project can then be related to resilience measures or case studies from the respective detail pages (see sections 4.3.2 and 4.3.4). In no other cases adding information about projects to the PEARL KB is meaningful.

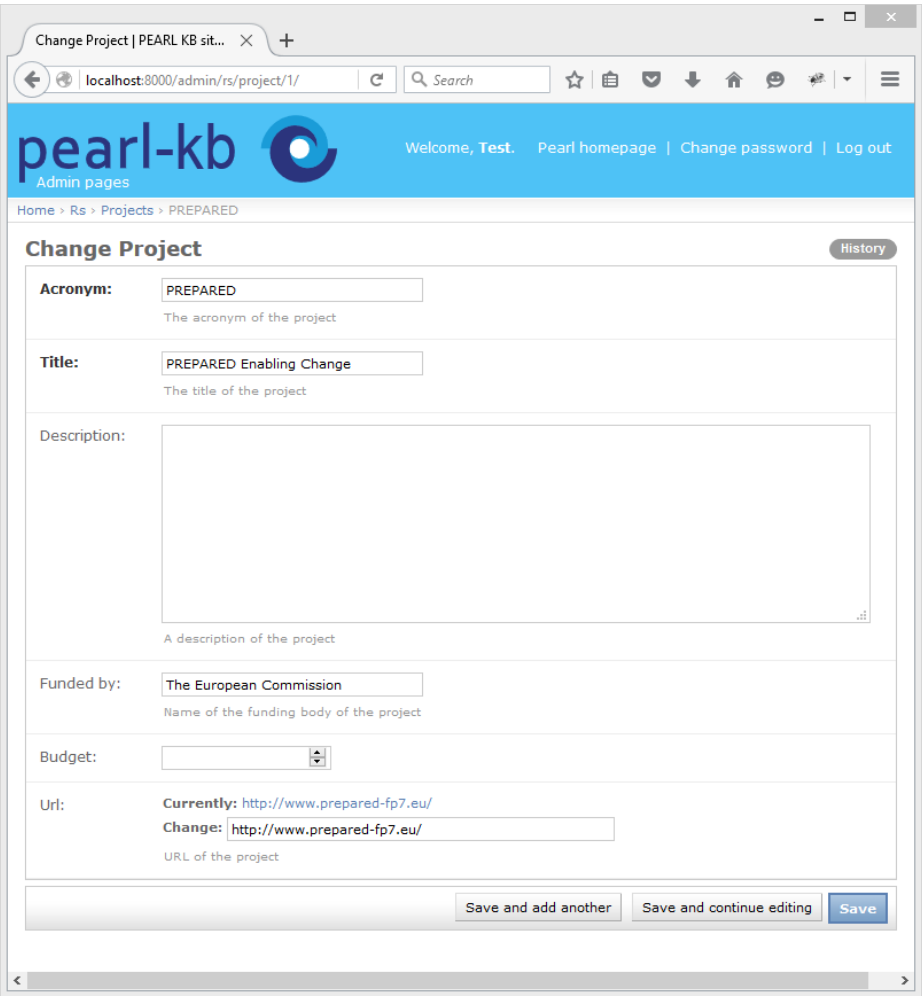


Figure 26: Project detail page

4.4 Modifying content

Through the admin pages an authorized user can also modify content stored in the Knowledge Base. One can navigate to the modification pages by selecting from the main menu: `Admin/Modify/...` (Figure 27).

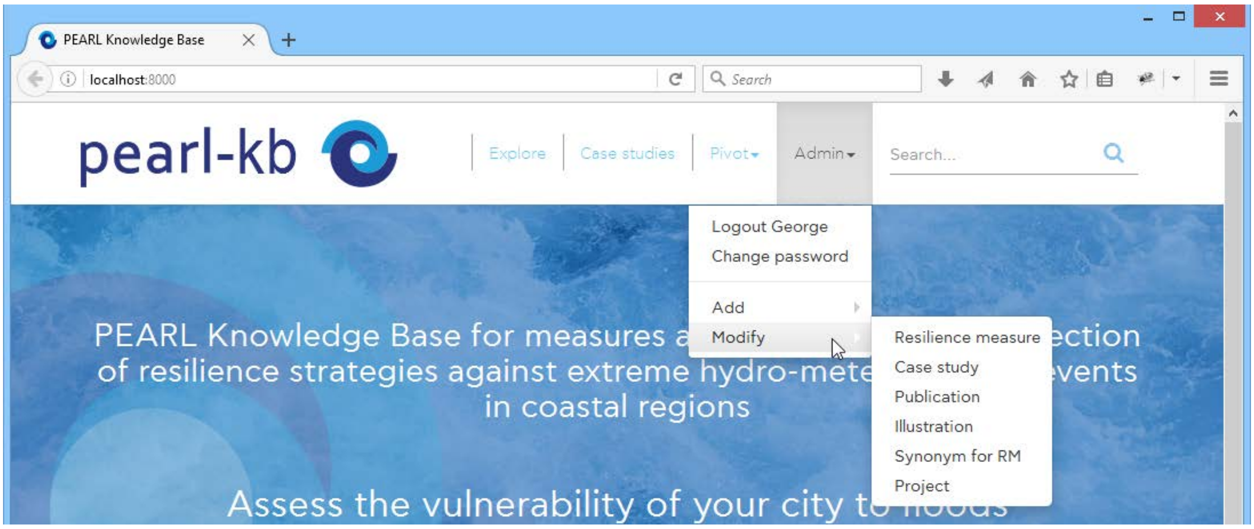


Figure 27: Navigating to the modification pages

	Data providers are allowed to modify only the case study records they own, i.e. information related to case studies they have added previously. An attempt to change data provided by another user will fail. This restriction applies only to case studies.

References

Batica J.; Gourbesville P.; Fang-Yu Hu. Methodology for Flood Resilience Index. In International Conference on Flood Resilience: Experiences in Asia and Europe, Exeter, United Kingdom, 2013.

CORFU project, Official website. http://www.corfu7.eu/ (accessed on December 2017)

Karavokiros G., A. Lykou, I. Koutiva, J. Batica, A. Kostaridis, A. Alves, and C. Makropoulos, Providing evidence-based, intelligent support for flood resilient planning and policy: the PEARL Knowledge Base, *Water*, 8 (9), 392, doi:10.3390/w8090392, 2016.

Levenshtein V. Binary codes capable of correcting deletions, insertions, and reversals. Soviet Physics Doklady 1966, 10, 707-710.

Annex 1 – Validation rules

Upon saving a record, a number of validation checks apply. Typically, validation checks include mandatory field checks and data type checks (e.g. integer or real number, text etc.). Additional validation checks apply per data category as shown in the following Table.

Data category	Filed	Rule
Illustration	Image	The size of the uploaded image must not exceed the limit of 1MB
Illustration	Case study or Resilience measure	The illustration should show a case study area and/or a resilience measure to be used a reference picture. At least one of these fields must be selected
Project	Acronym	All project acronyms must be unique.
Project	URL	The URL must start with `http://` or `ftp://` and follow specific syntax rules.
Synonym	Term	All terms must be unique, i.e. the new term should not be already in use by a resilience measure or a synonym.
Source	Case study or Resilience measure	The source/publication should provide information for at least one documented case study or resilience measure. At least one item from these fields must be selected
Source	Title	The title should not be already in use by another source
Source	Year	The year must range between 1800 and the current year
Source	Year	In case the source type is one of the following: Journal article, Book, Conference Paper/ Proceedings, Project Report, Newspaper, a valid year must be provided (conditional mandatory field)
Source	Publisher/Editor	In case the source type is one of the following: Journal article, Book, Conference Paper/ Proceedings, Project Report, Newspaper, a publisher/editor must be provided (conditional mandatory field)
Source	Authors	In case the source type is one of the following: Journal article, Book, Conference Paper/ Proceedings, Project Report, Newspaper, authors must be provided (conditional mandatory field)

Source	Keywords	In case the source type is one of the following: Journal article, Book, Conference Paper/ Proceedings, Project Report, Newspaper, one or more keywords must be provided (conditional mandatory field)
Source	Abstract	In case the source type is one of the following: Journal article, Book, Conference Paper/ Proceedings, Project Report, an abstract must be provided (conditional mandatory field)
Source	URL	In case the source type is Web resource URL must be provided (conditional mandatory field). The URL (if provided) must start with `http://` or `ftp://` and follow specific syntax rules.
Case study	Name	The name should not be already in use by another case study
Resilience measure	Name	Names must be unique, i.e. the new name should not be already in use by another resilience measure or a synonym.

Annex 2 – Description of attributes

Description of class attributes per data category

Data category	Attribute	Description
Resilience measure	Name	
Resilience measure	Definition	
Resilience measure	Benefits	
Resilience measure	Conditions	Any conditions that might influence the application of the measure
Resilience measure	Projects	Projects from which information has been harvested.
Resilience measure	Measure types	Type categories with which this measure is related.
Resilience measure	Problem types	Problem types for which this measure can be applied.
Resilience measure	Scales	Scales to which this measure can be applied.
Resilience measure	Land uses	Land uses in which this measure can be applied.
Resilience measure	Parent	The parent measure, in terms of this measure being a subcategory of the parent one
Resilience measure	Application target is adaptation	Indicate if the measure is suitable for adaptation
Resilience measure	Application target is mitigation	Indicate if the measure is suitable for mitigation
Resilience measure	Protection approach	Does the measure belong to this subcategory of measures?
Resilience measure	Accommodation approach	Does the measure belong to this subcategory of measures?
Resilience measure	Retreat approach	Does the measure belong to this subcategory of measures?
Resilience measure	Temporary approach	Does the measure belong to this subcategory of measures?
Resilience measure	Permanent approach	Does the measure belong to this subcategory of measures?
Resilience measure	Water retention or detention	Does the measure belong to this subcategory of measures?
Resilience measure	Rivers' Capacity Enhancement	Does the measure belong to this subcategory of measures?
Resilience measure	Coastal management	Does the measure belong to this subcategory of measures?

Resilience measure	Conventional urban drainage systems	Does the measure belong to this subcategory of measures?
Resilience measure	Source control	Does the measure belong to this subcategory of measures?
Resilience measure	Infiltration technique	Does the measure belong to this subcategory of measures?
Resilience measure	Conveyance & Storage Structure	Does the measure belong to this subcategory of measures?
Resilience measure	Information, Education & Communication	Does the measure belong to this subcategory of measures?
Resilience measure	Land use control	Does the measure belong to this subcategory of measures?
Resilience measure	Financial preparedness	Does the measure belong to this subcategory of measures?
Resilience measure	Flood preparedness & emergency response & infrastructures	Does the measure belong to this subcategory of measures?
Resilience measure	Recovery	Does the measure belong to this subcategory of measures?
Resilience measure	Comments	
Case study	Name	Distinctive name for the application or case study. It should be small and comprehensive and should have a reference to the region.
Case study	Location of the case study	Please give a location name for the case study (e.g. city or region)
Case study	Reference point	Please specify on the map a reference point (e.g. centroid) of the case study area
Case study	Description of the application	Please give a short description for the application of resilience measures (case study)
Case study	Application type	
Case study	Resilience measures	Which resilience measures have been applied? In case a combination of measure is applied, multiple selections can be made by keeping the ctrl key pressed.
Case study	Projects	Projects from which information has been harvested.
Case study	Impact before implementation	What is the impact of floods BEFORE the measures are implemented? Multiple selections can be made by keeping the ctrl key pressed.
Case study	Impact after implementation	What is the impact of floods AFTER the measures are implemented? Multiple selections can be made by keeping the ctrl key pressed.

Case study	Countries	Country in which the application (case study) is located. In case of a transboundary application multiple countries can be selected by keeping the ctrl key pressed.
Case study	Stakeholders	Other stakeholders involved.
Case study	Responsible authority level	Level of Responsible Authority.
Case study	Implementation cost	Estimated financial cost for the implementation of the measures.
Case study	Served purpose	How do you think the measure(s) served their purpose of implementation?
Case study	Site	
Case study	Transferable methodology	Is the methodology generic and transferable?
Case study	Lessons learned	
Case study	Comments	
Illustration	Image	Illustrations should have landscape orientation and their file format must be supported by web browsers (e.g. png, jpg). They should have high resolution and their size should not exceed 1MB.
Illustration	Caption	
Illustration	Source	The source of this illustration. Usually the copyright owner.
Illustration	Case study	Illustration of the case study area
Illustration	Resilience measure	Reference illustration of the resilience measure
Synonym of Resilience Measure	Term	A term that is a synonym for a known resilience measure
Synonym of Resilience Measure	Resilience measure	The name of the resilience measure for which the given term is a synonym
Synonym of Resilience Measure	Comments	
Project	Acronym	The acronym of the project
Project	Title	The title of the project
Project	Description	A description of the project
Project	Funded by	Name of the funding body of the project
Project	Budget	
Project	url	URL of the project
Source	Source type	Select the type of the source
Source	Title	The title of the source

Source	Case studies	Select one or more case studies to which this source is related (if applicable).
Source	Resilience measures	Select one or more resilience measures to which this source is related (if applicable).
Source	Authors	The names of the authors, separated by comma
Source	Year	The year of publication
Source	Publication	
Source	Publisher/ Editor	
Source	url	URL of the source
Source	Keywords	Keywords separated by comma
Source	Abstract	An abstract of the source content
Source	ISSN	International Standard Serial Number
Source	ISBN	International Standard Book Number

Annex 3 - List of Resilience Measures

The full list of resilience measures with links to detail pages is provided online under the following URL:

http://pearl-kb.hydro.ntua.gr/l/ResilientMeasure/

Name	Definition	Parent measure
Adjustment of fairway	Adjustment of the fairway contains every constructional measure to a navigable channel, e.g. Broadening of curved fairways, deepening of the fairway, part backfilling. These measures ensure certain fairway conditions and keep the fairway navigable for ships.	
Afforestation	Land use conversion is a general term for large scale geographic change. Afforestation is one such land conversion in which trees are planted on previously non forested areas. Depending on the tree species planted and the intensity of forest management, afforestation may have more or less environmental benefits. The greatest environmental benefits are probably associated with planting of indigenous broadleaves and low intensity forestry. Plantation forestry with exotic species is likely to be less beneficial to the environment. (NWRM, Land use conversion, access on Sept. 2016)	Increase of infiltration capacity
Amphibious building	Amphibious buildings lie on the ground out of flood periods and are likely to float when the water level rises during flood. They do not therefore float permanently unlike the floating buildings which can be found in many countries in urban areas along lakes or slow-flowing rivers. The principle is to erect the building structure on a float. When moving vertically with water level variations, these floats are guided by vertical posts to avoid the drift of the amphibious building. Flexible piping allows energy/water feeding and waste drainage. (Vojinovic Z., 2015, p. 124)	
Aquifer recharge	Aquifer recharge is achieved by adding surface water in basins, furrows, ditches, wells or other facilities where it infiltrates into the soil and recharges the aquifers. Aquifer recharge allows water retention underground. During flood events, water can be redirected to aquifer's area. (Bouwer H., 2001)	
Artificial sand dunes and dune rehabilitation	Naturally occurring sand dunes are wind-formed sand deposits representing a store of sediment in the zone just landward of normal high tides. Artificial dunes are engineered structures created to mimic the functioning of natural dunes. Dune rehabilitation refers to the restoration of natural or artificial dunes from a more impaired, to a less impaired or unimpaired state of overall function, in order to gain the greatest coastal protection benefits. (Climate Technology Centre & Network, Information related to Dune construction and stabilisation, accessed on Sept.	Managed realignment

Name	Definition	Parent measure
	2016)	
Beach nourishment	Beach nourishment is an adaptation technology primarily used in response to shoreline erosion, although flood reduction benefits may also occur. It is the process by which sediment (usually sand) lost through longshore drift or erosion. Beach nourishment is typically part of a larger coastal defense scheme. It is a soft engineering approach to coastal protection which involves the artificial addition of sediment of suitable quality to a beach area that has a sediment deficit. Nourishment is typically a repetitive process, since it does not remove the physical forces that cause erosion, but simply mitigates their effects. (Linham M. and Nicholls R., 2010)	
Bioretention area	A bioretention area is a stormwater treatment system that is a depression integrated into the landscape. A bioretention area captures runoff from an impervious surface and allows that water to infiltrate through the soil media. As the water infiltrates, pollutants are removed from the stormwater runoff through a variety of mechanisms including adsorption, microbial activity, plant uptake, sedimentation, and filtration. Some of the incoming runoff is temporarily held by the soil of the bioretention area and later "leaves" the system by way of evapotranspiration or exfiltration to the ground water. (Bioretention at North Carolina State University BAE, accessed on Sept. 2016)	Increase of infiltration capacity
Breakwater	Breakwaters are structures constructed on coasts as part of coastal defense or to protect a port and port entrance from the effects of both heavy sea state and longshore drift. They are build to reduce the intensity of wave action in the lee of the structure by a combination of reflection and dissipation of incoming wave energy. When used for harbors, breakwaters are constructed to create sufficiently calm waters for safe mooring and loading operations, handling of ships, and protection of harbor facilities. Breakwaters are also built to improve maneuvering conditions at harbor entrances and to help regulate sedimentation by directing currents and by creating areas with differing levels of wave disturbance. Protection of water intakes for power stations and protection of coastlines against tsunami waves are other applications of breakwaters. When used for shore protection, breakwaters are built in near shore waters and usually oriented parallel to the shore. (ASTARTE, Aydin D.C. et. al., 2014)	
Budget diversion	Governments of emerging-economy countries raise money for disaster response and rehabilitation by diverting funds from other budgeted items such as ongoing public infrastructure projects. (Kunreuther H. and Linnerooth-Bayer J., 1999).	
Building elevation	Building elevation is a measure mainly suitable for new constructions, but it can also be applied on existing buildings. The building is elevated to prevent flood waters entering the lowest floor of the building. This can be done by elevating the entire house, including the floor either on extended foundations, piers, piles or columns (normally, as a preventive measure), or	

Name	Definition	Parent measure
	by leaving the house in its existing position and constructing a new, elevated floor within the house (palliative). (Federal Emergency Management Agency, 2014)	
Building relocation	A building relocation is the process of moving a building from one location to another. There are two main methods for a building to be moved: disassembling and then reassembling it at the required destination or transporting it as a whole. Transporting the building as a whole involves lifting a building off its foundation, placing it on a heavy-duty flatbed trailer, hauling it to a new site outside the flood hazard area and lowering it onto a new foundation. The process requires careful planning. (Wikipedia, Structure relocation, accessed on Sept. 2016)	
Building without a crawlspace	Crawlspaces vent the underside of a building and thereby prevent the moulding of dry wooden floors. However, with the introduction of concrete slabs, such ventilation is no longer necessary and compared to crawlspaces provides several benefits for water management. If concrete slabs are used, groundwater tables will no longer have an impact on the structure. As a result it becomes possible to increase the variability of the groundwater table, which results in an increased water retention capacity in the area. This reduces the chance of flooding and increases the water availability in during periods of drought (Climateapp, Building without a crawlspace, accessed on Sept. 2016).	
Buildings as flood defence	New and existing buildings in flood risk areas can be used as flood defence. The buildings should be completely integrated in the flood defence to create a reliable flood defence (Urban Green-Blue Grids for sustainable and resilient cities, accessed on Sept. 2016).	Multi-functional flood defences
Bypass channel	Bypass channel, also known as a flood-relief channel, is an artificially made waterway constructed in order to protect urban and rural agricultural areas from flooding. It is built to carry excess water from a main stream or river so that it is translocated into the lower parts of the same stream or into another stream with the ability to accept a large amount of excess water. There are two types of bypass channels with regards to placement: parallel and transverse (vertical). The most common case of a parallel bypass channel is the one starting from the main river before the flood-prone section and reunited with the river after that section. In lowland areas, the construction of bypass channels is often combined with the construction of retention areas (Ahmad P. and Rasool S., 2014, p. 304).	
Canal and rill	Canals and rills are open surface water channels with hard edges. They are simply channels that water flows along whereby they can have a variety of cross sections to suit the urban landscape, including the use of planting to provide both enhanced visual appeal and water treatment. (Susdrain, Channels & rills, accessed on Sept. 2016 & NWRM, 53 NWRM illustrated, accessed on Sept. 2016)	Increased capacity of sewer/drainage system

Name	Definition	Parent measure
Cascading flood compartment system	The “system of cascading flood compartments” combines area prevention with constructional solutions. The idea is to (re)build a second dikeline of polders behind the primary dike, thereby creating a system of different compartments. Polders are low lying areas enclosed by embankments or dikes. In the case of a dike overflowing, the system diverts the water to the hinterland (Knieling J. and Schärffer M., 2011, p. 8).	
Check valve	A check valve or non-return valve is installed in pipes which are vulnerable for backflow in flood conditions. Backflow is known to take place in toilets and sewer systems. The valve will block flow if water flows in the “wrong” direction (Wikipedia, Check Valve, accessed on Sept. 2016).	
Coastal setback	Coastal setbacks are a prescribed distance to a coastal feature such as the line of permanent vegetation, within which all or certain types of development are prohibited. A setback may dictate a minimum distance from the shoreline for new buildings or infrastructure facilities, or may state a minimum elevation above sea level for development. Elevation setbacks are used to adapt to coastal flooding, while lateral setbacks deal with coastal erosion (ClimateTechWiki, Coastal setbacks, accessed on Sept. 2016).	
Community involvement	Community involvement is a bottom up approach which involves the community in decision-making process. For example, communities living in flood-prone areas are actively engaged in the identification, analysis, planning, monitoring and evaluation of disaster risk (including flood) in order to reduce their vulnerabilities and enhance their capacity.(Stam C.J., 2015)	Public awareness, information, education and communication
Conventional urban drainage systems	The purpose of urban drainage systems (a.k.a. collection systems) is to enable safe and reliable disposal of stormwater runoff (i.e., they are at the first place used for pluvial flood protection) and removal of wastewater from urban areas. These systems can be either combined, separate or hybrid. They can be in the form of open channels or closed conduits. The term ‘sewers’ usually refers to the network of closed conduits (i.e., piped systems) which are used to convey the flow from a certain area, whereas the term ‘sewerage’ refers to the entire wastewater/stormwater system infrastructure in the particular city. The key elements of urban drainage systems are: reticulation or collection networks (pipes, rising mains, channels, culverts, manholes, etc.), gully inlets (a.k.a., catchpits), ventilation shafts, chambers and tanks, combined sewer overflows and sanitary sewer overflows, outfalls, controls (orifices, gates, penstocks, vortex regulators, flap valves, etc.), pumping stations, bifurcations, weirs, inverted siphons, treatment and other ancillary structures, storages (offline, online, open, closed, above-ground, below-ground, retention and detention ponds), watercourses, boverland flow paths and designated floodplains, dams, multipurpose tunnels and so on (Vojinovic Z., 2015, p. 97).	Increased capacity of sewer/drainage system
Creation of a	A second dike line is created by building other dikes, mostly	Dike

Name	Definition	Parent measure
second dike line	bigger dikes, on the water side of existing dikes, which will not be removed. Building of new and bigger dikes can be necessary due to e.g. increased storm surges activities (higher water levels, more frequent occurrence of storm surges). The newly built dike provides the protection against the storm surges. The still existing dike is then referred to be the second dike line (or summer dike) and provides a further protection by creating an additional volume that can be flooded.	
Data collection	Data collection is the process of gathering and measuring information on targeted variables in an established systematic fashion, which then enables one to answer relevant questions and evaluate outcomes (Wikipedia, Data Collection, accessed on Sept. 2015). Especially in flood risk management, when a major incident occurs and government is providing support to impacted areas, then it is important that a more accurate record of flood impacts is developed e.g. in order to target funds. At this stage data is likely to be collected by local authorities and will be differentiated between homes and businesses. The numbers should be confirmed rather than estimated. (Department for Environament, Food and Rura Affairs & Environment Agency, 2014) Data Collection is important prior and after a flood event, while the collected information might serve on several issues and processes.	
Deculverting of watercourses	This activity involves techniques to resolve the issues created by culverted watercourses. This is predominantly through deculverting, or 'daylighting' which involves opening up buried watercourses and restoring the bed, bank and riparian corridor to more natural conditions (European Centre for River Restoration, Remove Culverts, accessed on Sept. 2016).	Increased capacity of sewer/drainage system
Demountable flood protection barrier	Demountable flood protection barriers consist of a combination of removable and pre-installed permanent components. The system is planned to be erected following a flood warning and dismounted after the end of a flood warning. Contrary to the temporary flood barriers, the site of use is constrained by the location of the pre-installed components (foundation). Generally, the demountable components are composed of pillars, which are fixed after the warning alert to the pre-installed ground components. Between the pillars the protection line is inserted, which may consists of beams or plates. (Ogunyoye F. et. al, 2011)	
Dike	A dike or levee is an elongated artificially constructed embankment, which protects low-lying areas against higher water levels. It is usually made of clay and sand. Rock or concrete are used to protect the water facing outer slope against waves. Most dikes are constructed parallel to the course of a river in its floodplain or along low lying coastlines. (Wikipedia, Levee, accessed on Sept. 2016) Similarly to dikes, the primary function of sea dikes is to protect low-lying, coastal areas from inundation by the sea. It is a predominantly earth structure consisting of a sand core, a watertight outer protection layer, toe protection and a drainage	

Name	Definition	Parent measure
	channel. These structures are designed to resist wave action and prevent or minimise overtopping. They can be realised as linear structures (even closed dike line) or as a closed circular structure (ring dike). Additionally, dikes can be used for land reclamation by diking of marshes. (ClimaTechWiki, Sea dikes, accessed Sept. 2016)	
Dike inspection and/or recovery	Inspection of the flood protection dikes takes place in order to observe and assess the state of the dike and especially after a storm surge events to locate damages in the dike line. Located damages will be fixed (dike recovery) to maintain the protective effect of the dike. It is the responsibility of the diking maintenance authority, or the private owner, to conduct routine and periodic inspections and maintain and repair the works to the same flood protection standard that the works were built to. Necessary funds shall be budgeted annually and set apart for the specific purpose of maintenance and repair of the flood control works. The entire flood protection system shall be inspected in detail at least once every year. Such inspections shall be scheduled prior to the high flow season allowing sufficient time to carry out any repair work needed to put the works back to design standards. Additional inspections may be necessary after each winter season to check slope erosion or sloughing, frost damage or vehicle damage to the dike crest, access ramps, access roads and turn arounds. (Golder Associates Ltd. And Associated Engineering B.C. Ltd., 2003)	Dike
Dike reinforcement	Dike reinforcement describes the process of strengthening the dike by e.g. raising the dike height, widening of the dike crest, broadening the whole structure etc. This process tend to adjust the cross section of the dike to changed loads on the dike e.g. more extreme and more frequent occurring storm surges.	Dike
Dike relocation	A new dike is built further away from the river or the coast after which the existing dike is removed. This leads to an increase of the flood plain. Within the framework of the EU flood risk policy, the creation of new retention areas by dike relocation is a major task in European river basin management. (Helmholtz Centre for Environmental Research – UFZ, Dike relocation, accessed on Sept. 2016)	Dike
Ditch	A ditch is usually defined as a small to moderate depression created to channel water. A ditch can be used for drainage, e.g. to drain water from low-lying areas, alongside roadways or fields, or to channel water from a more distant source for plant irrigation. A trench is a long narrow ditch. Ditches are commonly seen around farmland especially in areas that have required drainage such as low land areas. Ditches can also carry off excess water or sewage. (Wikipedia, Ditch, accessed on Sept. 2016)	Increased capacity of sewer/drainage system
Dredging of watercourse	The term dredging is used to refer to the systematic removal of accumulated material from river or other watercourse channels. In its most	

Name	Definition	Parent measure
	extreme form dredging may be used to re-align river channels creating linear, canalised watercourses. While implementing such a measure the cross section of channels and waterways is enlarged i.e. their carrying capacity is increased assisting in carrying flood flows. (CIWEM, 2014).	
Dry-floodproofing technology	Dry floodproofing is a method of flood preparation that involves building designs and material choices that do not allow for the entry of floodwaters into the structure. This resilience measure should be designed to account for the height of building flood elevations, buoyancy and hydrostatic pressures of flood waters, and wave action. Dry floodproofing differs from wet floodproofing in that wet floodproofing measures allow the entry of water (see figure at right for further comparison). Dry floodproofing measures are: sealing building walls, permanently seal openings, flood shields for openings, interior drainage. (DDC Building Resilience Database, Dry floodprofing, accessed on Sept. 2016)	
Dwelling mound	A dwelling mound is an artificial hill made from earth, created to provide safe ground for humans and animals during storm surges. This concept has been applied to the Hafen City Hamburg which involves the heightening areas and access routes based on the model of the dwelling mounds. The dwelling mounds can be connected by building of dikes in between them, in order to create a larger continuous protected area.	
Elaboration of municipal archives on major hazards	Through municipal archives, citizens will be able to be kept informed about both the natural and technological risks to which the municipality has been subjected throughout the years as well as the implementation of selected measures aiming at prevention, forewarning and protection.	
Emergency exit of buildings above highest flood level	The main exit of a building is traditionally positioned at ground level. In case of a flood this only exit may be blocked by water and debris taken by the waterflow. Emergency exits should be placed at the highest possible flood level. Also existing windows can be redesigned as emergency exits. (Climate app, Emergency exit of buildings above highest flood level, accessed on Sept. 2016)	
Emergency operation centre and personnel	An Emergency Operation Centre (EOC) is a central location where response personnel can coordinate and make decisions in support of emergency response activities at the site level. Emergency preparedness involves as much pre-planning as possible and the designation of a variety of emergency facilities can enhance response logistics when an emergency occurs. The EOC integrates personnel, procedures, communications and equipment into a common system with responsibility for coordinating an emergency event such as flood event (Emergency Management BC, 2011, p. 1).	Flood emergency framework

Name	Definition	Parent measure
Emergency supplies and utilities	Emergency supplies and utilities are necessary in case of a flood emergency. It should consist of food and drinks, first aid kit and other provisions to survive or continue operating for instance a hospital or business. (Climate app, Emergency supplies and utilities, accessed on Sept. 2016)	Flood emergency framework
EU Flood Risk Management Directive	EU adopted the Flood Risk Management Directive. Directive 2007/60/EC on the assessment and management of flood risks entered into force on 26 November 2007. This Directive now requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. With this Directive also reinforces the rights of the public to access this information and to have a say in the planning process. (European Commission, Directive 2007/60/EC, accessed on Sept.2016)	
Evacuation plan	The purpose of evacuation is to relocate people temporarily from areas at risk of the consequences of flooding to places of safety. Emergency evacuation plans are developed to ensure the safest and most efficient evacuation time of all expected residents of a structure, city, or region. A benchmark "evacuation time" for different hazards and conditions is established. These benchmarks can be established through using best practices, regulations, or using simulations, such as modelling the flow of people in a building, to determine the benchmark. Proper planning will use multiple exits, contra-flow lanes, and special technologies to ensure full, fast and complete evacuation. Consideration for personal situations which may affect an individual's ability to evacuate is taken into account, including alarm signals that use both aural and visual alerts, and also evacuation equipment such as sleds, pads, and chairs for non-ambulatory people. Regulations such as building codes can be used to reduce the possibility of panic by allowing individuals to process the need to self-evacuate without causing alarm. Proper planning will implement an all-hazards approach so that plans can be reused for multiple hazards that could exist. The sequence of an evacuation can be divided into detection, decision, alarm, reaction, movement to an area of refuge or an assembly station transportation. (Wikipedia, Emergency evacuation, accessed on Sept. 2016)	Flood emergency framework
Evacuation routes at elevated level	Evacuation routes at an elevated level are necessary as a route for safe evacuation in flood events. They should be constructed above the highest expected flood level. People affected by the floods can use the routes to reach safe (higher) ground. (Climate app, Evacuation routes at elevated level, accessed on Sept. 2016)	Flood emergency framework
Family emergency planning	Disasters and emergencies such as floods can affect people in any part of the world and at any time of the year, swiftly and without warning. Even small events, such as a power outage, can quickly have disastrous effects for a family that is not prepared. Families	Flood emergency framework

Name	Definition	Parent measure
	must work together to prepare for unexpected situations. Family emergency planning can be the key to surviving an emergency. Family emergency planning includes all actions necessary to be implemented by all members of the family, prior during and after a flood event which will ensure that family will be ready for a disaster whether the members are at home or not. Specifically, family emergency planning would include: creation of a family disaster supply kit, development of a family preparedness plan, identification of a local or/and regional meeting place and practice of the family plan (FEMA, 2011, p. 1).	
Fascine	A fascine is a bundle of sticks or brushwood used in construction, generally to strengthen an earthen structure, fill ditches, or make a path across uneven or wet terrain. Live fascines are bundles of live branches intended to grow and produce roots. They can be placed in shallow trenches on a stream bank to reduce erosion across the bank and increase soil stability. The rooted branches protect the toe of the stream bank from erosion and improve infiltration. Properly placed, the bundles can also trap debris and sediment. Live fascines can also be used to reinforce slopes and increase drainage and infiltration. They are installed perpendicular to the slope in dug trenches or in existing gullies and rills. (Shrestha, A. B. et. al., 2012, p. 26)	
Filled container	These are cellular barriers filled with aggregates or water to form a barrier against floodwater. Containers can be divided into two categories, permeable and impermeable. In both cases, they serve as gravity dams, using the weight of the aggregate or water for stability. These containers are another example of temporary flood protection systems. Filled permeable containers are cellular barriers made of permeable materials such as geo-textile or geosynthetic fabrics and filled with aggregates to form a barrier against floodwater. Some containers are strengthened and held in place by wire meshes, pins and frames. On the other hand, filled impermeable containers are made of impermeable materials such as polyester, polyethylene and plastic. The containers themselves are impermeable and are filled with water or aggregates only to provide additional weight. These systems are gravity structures achieving stability through their weight and shape (Ogunyoye F. et. al, 2011, p. 41).	Floodwall
Filter drain	A filter drain is a gravel filled trench, generally with a perforated pipe at the base. Runoff flows slowly through the granular material, trapping sediments and providing attenuation. Flow is then directed to a perforated pipe, which conveys run-off either back into the sewerage network or into a waterbody. Filter drains are mainly used to drain road and carpark surfaces. Ideally these systems are used as a component of a treatment train. (Clifton Scannell Emerson Associates Limited, 2011, p. 38)	Filter trench
Filter strip	Filter strips are gently sloping, vegetated strips of land that provide opportunities for slow conveyance and infiltration (where appropriate). They are designed to accept runoff as overland	Increase of infiltration capacity

Name	Definition	Parent measure
	sheet flow from upstream development and often lie between a hard-surfaced area and a receiving stream, surface water collection, treatment or disposal system. (Susdrain, Filter strip, accessed on Sept. 2016)	
Filter trench	Filter trenches are shallow excavations filled with rubble or stone that create temporary subsurface storage of stormwater runoff. These trenches can be used to filter and convey stormwater to downstream SuDS components. Its performance in peak flow reduction is medium and in volume reduction low. (Susdrain, Filter trench, accessed on Sept. 2016)	Increase of infiltration capacity
Flexible water level management	Flexible water level management involves anticipating precipitation that has been forecast. The water level is lowered before a shower is expected, to create additional water storage capacity. By using flexible natural fluctuations in the water level, improvements can be achieved in rainfall runoff characteristics. In wet periods water levels are allowed to rise, in dry periods water levels are allowed to lower. This reduces the use of pumping stations or water inlet systems. (Urban Green-Blue Grids for sustainable and resilient cities, Flexible water level management, accessed on Sept. 2016) Example of this measure is the management of water level of swamps which establishes water level management arrangements in existing marshes during pre-alert, alert and after crisis and enabling/increasing water storage capacity.	
Floating agricultural system	Floating agriculture is a way of utilising areas which are waterlogged for long periods of time in the production of food. The technology is mainly aimed at adapting to more regular or prolonged flooding. The approach employs beds of rotting vegetation, which act as compost for crop growth. These beds are able to float on the surface of the water, thus creating areas of land suitable for agriculture within waterlogged regions. Scientifically, floating agriculture may be referred to as hydroponics. (ClimateTechWiki, Floating agricultural system, accessed on Sept. 2016)	
Floating building	The basic characteristic of floating buildings is that they are not supported by a firm foundation, but float on water. Traditional foundations are therefore not required. The position of a floating building is permanently fixed in a horizontal direction, while it can flexibly follow vertical variations in water level. The base of a floating home consists of a floating mechanism that secures the building's buoyancy. The bottom level of the entire construction should be at least 1 meter from the water bottom in order to maintain favourable water quality conditions. It is essential that a floating building never touches firm ground, because the construction is not designed for such conditions. The floating mechanism that is positioned at the basis of the floating structure can consist of high-density expanded poly-styrene or a hollow, concrete structure. Hollow space can be used for storage of light goods. Floating homes can have terraces that can be regarded as a small-scale version of traditional gardens. Infrastructure connections to floating buildings should be designed so at to be	Flood proof infrastructure

Name	Definition	Parent measure
	able flexibly cope with expected water level variations. (SlideShare, Floating technology, accessed on Sept. 2016)	
Floating road	Road transport infrastructure and evacuation routes that are prone to flooding need to be flood proofed to reduce the vulnerability and negative impacts of flooding of transport routes. Available options to reduce the negative impacts of flooding are not only maintenance of infrastructure and the use of appropriate design and materials, but also creation of floating roads or elevated roads for evacuation routes. Floating roads are literally roads that float on the water. Ideally they are flexible in both time and space; they do not only float but can also move to accommodate a changing water level. Instead of a fixed bridge it consists of a series of floating pontoons on which vehicles can drive. Elevated roads can look like a fixed bridge, but are longer and form a network of streets leading to higher grounds. An elevated road can also be a road on top of a bank, thus elevated with sand. Elevated (or flood protected) roads are useful when a city is vulnerable for flooding. When regular roads are turned into rivers, the citizens can still evacuate using the elevated (or flood protected) roads. Floating roads are more flexible than bridges and can also be useful as a bypass in the event of road blockages by reasons other than flooding, e.g. due to roadwork on a bridge or road along a waterway. They might look like a traditional bridge construction but with floating supports instead of fixed ones or it might be a series of floating pontoons over which a vehicle can be driven. The floating road could provide access in areas where water is regularly allowed to overflow as a control mechanism and could be a permanent fixture in areas with weak ground such as peat. This kind of solution to roadworks would minimise disruption, but it would have to be quick to assemble and easy to relocate. Taking less space than traditional alternatives, floating roads would be very much in line with innovative thinking about using space in a variety of ways. (European Climate Adaptation Platform, Floating or elevated roads, accessed on Sept. 2016) & (TNO Traffic and Transport, 2003).	Flood proof infrastructure
Flood control dam	A flood control dam is a dam built to catch surface runoff and stream water flow in order to regulate the water flow in areas below the dam. Flood control dams are commonly used to reduce the damage caused by flooding or to manage the flow rate through a channel. (Wikipedia, Detention dam, accessed on Sept. 2016) In general, dams are multipurpose, therefore even when their main purpose of construction is different e.g. irrigation, water supply, hydro power etc., they always assist in flood protection due to the temporal regulation of flow they provide. (ICOLD, Role of Dams, accessed on Sept. 2016)	
Flood detention reservoir	Flood detention reservoir, also known as an attenuation or balancing or flood control reservoir or detention basin, collects water at times of very high rainfall and then releases it slowly over the course of the following weeks or months. Some of these reservoirs are constructed across the river line with the onward flow controlled by an orifice plate. When river flow	

Name	Definition	Parent measure
	exceeds the capacity of the orifice plate water builds behind the dam but as soon as the flow rate reduces the water behind the dam slowly releases until the reservoir is empty again. In some cases such reservoirs only function a few times in a decade and the land behind the reservoir may be developed as community or recreational land. This new generation of balancing dams are being developed to combat the climatic consequences of climate change. Because these reservoirs will remain dry for long periods, there may be a risk of the clay core drying out reducing its structural stability. Recent developments include the use of composite core fill made from recycled materials as an alternative to clay. (Sensagent, Flood detention reservoir, accessed on Sept. 2016) They also facilitate some settling of particulate pollutants. Detention basins are normally dry and in certain situations the land may also function as a recreational facility. However, basins can also be mixed, including both a permanently wet area for wildlife or treatment of the runoff and an area that is usually dry to cater for flood attenuation. (Susdrain, Detention reservoir, accessed on Sept. 2016)	
Flood emergency framework	Flood emergency framework sets out the government's strategic approach to achieving the aims set out below and is intended for use by all those involved in planning for and responding to flooding from the sea, rivers, surface water, ground water, reservoirs, artificial waterways and canals. Its purpose is to provide a forward looking policy framework for flood emergency planning and response. It brings together information, guidance and key policies and it is a resource for all involved in flood emergency planning at municipal, regional and national levels. It is a common and strategic reference point for flood planning and response for all tiers of government and for organisations. This provides guidance to the citizens in case of an extreme event that occurs by assuring(insuring) the alert, the information, the protection and the support of the population. (Department for Environment, Food & Rural Affairs, Environment Agency and Public Health England, 2014) Continual simulations of incidences and inter-agency response trials are needed to ensure that the framework works as planned.	
Flood forecasting and early warning	Flood forecasting is an important component of flood warning. Flood forecasting involves prediction of water levels and flows at particular locations at a particular time, while flood warning is the task of making use of the flood forecasts to make decisions on whether flood warnings should be issued to the general public. A flood warning system is a way of detecting threatening events in advance. This enables the public to be warned so that actions can be taken to reduce the adverse effects of the event. As such, the primary objective of a flood warning system is to reduce exposure to flooding. Typically it is the role of the flood modeler or manager to pass on information to the appropriate authorities, which then has the responsibility to warn the general public or properties of the impending flood risk (René R., et.al., 2013, p. 3). Flood forecasting and early warning is carried out to reduce risks in flood prone areas. This tool is tailored for use when decision-	

Name	Definition	Parent measure
	makers need to establish an effective overview of the flood situation, provide timely and accurate early warnings and flood forecasting services to a variety of users. Many countries have already integrated flood forecasting and early warning measures into their local and national emergency planning systems. This tool provides a concise overview of concepts and approaches in flood forecasting and early warning that helps flood managers and practitioners to develop and operate flood forecasting and early warning systems in flood prone areas. (Associated Programm on Flood Management, accessed on Sept. 2016)	
Flood gate	These barriers are made of a single or pair of rigid sections (usually steel or fibreglass), designed to close a gap within a flood defence. They are normally fully pre-installed and only require closure during an emergency. The closure operation can be manual, semi-automated or automatic. Automatic operation can be controlled by sensors and actuators, or by direct hydraulic link to the watercourse. They are normally attached to an adjacent structure or permanent protection or laid flat into a recess within the ground. Manual closure normally involves swinging, rolling or raising into position (Ogunyoye F. et. al, 2011, p.57).	Flood proof infrastructure
Flood hazard mapping	Flood hazard mapping is an exercise to define those areas which are at risk of flooding under extreme conditions. As such, its primary objective is to reduce the impact of flooding through better predictive capacity. It acts as an information system to enhance our understanding and awareness of flood risk. Creation of evolutionary mapping of the extreme meteorological events and their consequences, using GIS systems so that a bank of historic data can be constituted will result in easily-readible, rapidly-accessible charts and maps which facilitate the identification of areas at risk of flooding and also helps prioritise mitigation and response efforts. (ClimateTechWiki, Flood hazard mapping, accessed on Sept. 2016)	Vulnerability assessment
Flood insurance	Flood insurance is an important risk management tool that can be applied at various levels: individual, corporate and government. It provides a mechanism for sharing potential economic losses with others. The basic principle is to spread the risks over time, and among individuals and organizations, which pay insurance premium against a specific risk. Insurance can play an important role in a nation's social and economic recovery by channelling funds for rebuilding purposes through insurance payments. Coupled with the appropriate land use control and flood emergency management measures, flood insurance can serve as a useful tool to deal with residual risks. (Associated Programm on Flood Management, accessed on Sept. 2016)	
Flood proof infrastructure	Evacuation routes and infrastructure in cities that are prone to flooding need to be flood proofed. Available options to reduce the negative impacts of flooding are maintenance and condition of infrastructure, use of appropriate design and materials, creation of floating roads and creation of elevated roads for evacuation routes.	

Name	Definition	Parent measure
Flood shelter	Flood shelters are created in areas which experience severe flooding. Elevated flood shelters should be constructed above the highest expected flood levels. They should be easily accessible and should be able to accommodate all people in the vicinity (Climate app, Flood shelter, accessed on Sept. 2016). Flood shelters may help in saving lives and properties. These shelters can be used to manage relief and rehabilitation activities in an organized way. Providing shelter in the most vulnerable areas, which cannot be protected by structural measures due to practical reason, seems to be a plausible solution. According to Bangladesh typology, flood shelter could be categorised in community flood shelter, school-cum shelter and shelter for individual families. (Alam M.J.B and Hossain Alip Md., 2002, . 177)	Multi-functional flood defences
Floodplain excavation	Floodplain excavation is a measure by which gradual height increase caused by sedimentation on flood plains may be counteracted. The floodplain can be enlarged by lowering the level or increasing the width of the floodplain. Enlarging the floodplain will create more room for the river thereby increasing the discharge capacity and provide upstream retention. The risk of flooding is decreased as the capacity of the river to convey water is increased. (Climate app, Floodplain excavation or enlargement, accessed on Sept. 2016) Floodplain excavation may be combined with clay mining and dike reinforcement, and/or with nature development. The removal of hydraulic obstacles is another way to increase its discharge capacity without increasing its water level.Examples of hydraulic bottlenecks include ferry ramps, bridge abutments, high-lying areas, summer embankments that are high and/or perpendicular to the flow direction, narrowing of winterbeds and other obstacles (Knight D.W. and Shamseldin A., 2006, p. 546).	
Floodwall	A floodwall is a primarily vertical artificial barrier designed to temporarily contain the water of a river or other waterway which may rise to unusual levels during seasonal or extreme weather events. They can be realised as mobile flood protection walls, which are build up before a storm event occurs and which are removed after the storm event. Flood walls can also be installed as permanent structures. Flood walls are mainly used on locations where space is scarce, such as cities or where building levees or dikes (dykes) would interfere with other interests, such as existing buildings, historical architecture or commercial use of embankments. (Wikipedia, Flood wall, accessed on Sept. 2016 & Geocatching, Williamson Floodwall, accessed on Sept. 2016)	Permeable paving
Frame barrier	Frame barriers consist of rigid frames with impermeable membranes or sections spanning between them. They rely on supporting frames and the weight of the water to provide the barriers stability. They are modular and are connected together to form a continuous barrier. Frame barriers can be further sub-divided into flexible and rigid types. These sub categories refer to the materials which span between the frames to provide the	Floodwall

Name	Definition	Parent measure
	barrier. These containers are another example of temporary flood protection systems. Frame barriers can be either flexible or rigid. Flexible barriers consist of metal frames with flexible impermeable membranes spanning between them. The impermeable membrane extends upstream to form a long skirt and relies on the weight of the water acting on the membrane for increased stability and sealing with the ground surface. The rigid ones consist of metal frames with rigid panel elements that span between the frames which are often covered by an impermeable membrane. The separate units are connected together to form a continuous barrier. (Ogunyoye F. et. al, 2011, p.46)	
Freestanding barrier	These modular systems are made of impermeable materials and are joined together to form a continuous barrier or wall. These products are self supported and do not rely on frames. Free-standing barriers are divided into two groups, flexible and rigid. These containers are another example of temporary flood protection systems. Flexible free standing barriers are made of free-standing sections, which are self-supporting. The barrier material is flexible and impermeable. The stability of these barriers depends on direct anchorage or the weight of water acting on a long skirt on the upstream side of the defence. The length of the skirt is designed to ensure adequate stability. These are often weighted at the ends to minimise seepage. Rigid barriers may differ in design, however, their behaviour under operation and hydraulic loading are similar. These barriers are made of rigid self supporting units which connect together to make a continuous barrier or wall. They are made of rigid single elements, prefabricated materials or hinged panels with internal supports. Seepage under the barriers can be significant in uneven terrain due to their rigidity (Ogunyoye F. et. al, 2011, p.43).	Floodwall
Government debt instrument	A common way for emerging-economy governments to raise funds after a disaster is to borrow from their central bank reserves or to issue government bonds (Kunreuther H. and Linnerooth-Bayer J., 1999, p.14).	
Green roof	Green roof belongs in the category of SUstainable Drainage Systems (SUDS) and aims at source controlling. A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. Primary objective is the reduction of storm-water runoff as part of a sustainable drainage system. (Wikipedia, Greem roof, accessed on Sept. 2016)	Increase of infiltration capacity
Green wall	A green wall is a wall partially or completely covered with vegetation that includes a growing medium, such as soil. Most green walls also feature an integrated water delivery system. Green walls are also known as living walls or vertical gardens. The wall helps reduce run-off by capturing rainwater from the roof of the building in dedicated storage tanks.(Wikipedia, Green wall, accessed on Sept. 2016).	
Groyne	A groyne is normally a straight structure perpendicular to the shoreline. Groynes work by blocking (part of) the littoral drift,	

Name	Definition	Parent measure
	whereby they trap/maintain sand on their upstream side. Groynes can have special shapes and they can be emerged, sloping or submerged, they can be single or in groups, the so-called groyne fields. Groynes are normally built as rubble mound structures, but they can also be constructed in other materials, such as concrete units, timber, etc. A groyne is an active structure extending from shore into sea, most often perpendicularly or slightly obliquely to the shoreline. Adequate supply of sediment and existence of satisfactorily intensive longshore sediment transport are the sine qua non conditions of groynes efficiency. Catching and trapping of a part of sediment moving in a surf zone (mainly in a longshore direction), as well as reduction of the sediment amount transported seawards, are the principle functions of the groynen structural terms, one can distinguish between wooden groynes, sheet-pile groynes, concrete groynes and rubble-mound groynes made of concrete blocks or stones, as well as sand-filled bag groynes.As revealed by experiments, during weak and moderate wave conditions, the groynes partly dissipate energy of water motion and lead to sand accumulation in the vicinity of a shore, thus causing its accretion. Under storm waves, mainly approaching the shore perpendicularly, the role of the groynes decreases and a beach is partly washed out. Groynes are frequently used. However, applied as a self-contained shore protection measure it is a very dubious solution. This is because of unfavourable side effects which they can cause locally. Satisfactory supply of sand and existence of longshore sediment transport are fundamental conditions for efficiency of groynes. The groynes role distinctly increases if they are applied together with other (soft) shore protection measures, like artificial beach nourishment or shore nourishment. (Coastal Wiki, Groyne, accesed on Sept. 2015)	
Gutter	A gutter is a non-permeable open drain to collect transport rainwater. Usually a gutter runs along a road. It is connected to either a manhole or a surface water body (Huizinga R.P., 2015, p. 60). A gutter alleviates water buildup on a street, allowing pedestrians to pass without walking through puddles and reducing the risk of hydroplaning by road vehicles. When a curbstone is present, a gutter may be formed by the convergence of the road surface and the vertical face of the sidewalk; otherwise, a dedicated gutter surface made of concrete may be present Depending on local regulations, a gutter usually discharges in a storm drain whose final discharge falls into a detention pond (in order to remove some pollutants by sedimentation) or into a body of water. (Wikipedia, Street gutter, accessed on Sept. 2016)	Conventional urban drainage systems
High water mark	A high water flood mark is a point that represents the maximum rise of a body of water over land. Such a mark is often the result of a flood and aims at protecting the collective memory of citizens against flood risk and raising people's awareness (Wikipedia, High water mark, accessed on Sept. 2016).	Public awareness, information, education and communication
Hydraulic filling	Hydraulic Fill is fill in which the materials are deposited by a flowing stream of water. This fill material will originate from a borrow area or dredging site and be transported to the	

Name	Definition	Parent measure
	reclamation area by dredger, barge or pipeline. It is then placed as a mixture of fill material and process water in the reclamation area. Hydraulic Fill has a wide variety of applications for infrastructure construction projects. (IADC, 2012)	
Hydrological and Meteorological Observatory	Hydrological and Meteorological Observatory is an observation service dedicated to long-term monitoring of climatological and hydrological changes. It gathers data from an observation network located at different latitudes so as to sample the characteristic eco-climatic gradients of the region. Recorded data might be utilised in different parts of flood management procedures while analysis of this data will provide further information on evolution of flood risk and trends (based on AMMA-CATCH accessed on Sept. 2016).	Flood forecasting and early warning
Improved construction site preparation	Improved construction site preparation is focused on improving the strength and drainage capabilities of an area that is converted from a rural or nature area to an urban area. It should be done before construction of buildings is started. Main aspects of improved construction site preparation are investing in preloading of the soft subsoil with sand or solid soil, construction of groundwater drains and creation of a surface water system (Huizinga R.P., 2015, p. 60).	Increase of infiltration capacity
Increase of infiltration capacity	Improving the soil infiltration capacity means improving the permeability of the soil. If the infiltration capacity of the soil is increased, more water will percolate into the soil and less water will runoff directly. This will reduce peak runoff and promoted groundwater recharge.	
Increased capacity of sewer/drainage system	Increasing the capacity of the sewer/drainage system increases the ability of the system to drain excess surface water during heavy rains and prevent flooding. The capacity of stormwater systems may be increased by new and larger pipes when old pipes cause problems with flooding, pollution, etc. or even with maintenance works ensuring that the capacity of the system will be as designed (e.g. sediments trapped). (Torgersen G., et. al., 2014).	
Independent commission for flood and disaster risk reduction	An Independent commission is a politically independent executive arm. It is alone responsible for drawing up proposals for new legislation. (European Union, European Commission, accessed on Sept. 2016). Creation of a department for disaster risk reduction could be another form of such independent committee working on flood related issues.	
International loan	Emerging-economy governments have the opportunity to borrow at low interest rates from international lending organizations aiming at pre-disaster planning or at recovery activities before or after the occurrence of extreme event respectively. This is a major financing source in the developing world. (Kunreuther H. and Linnerooth-Bayer J., 1999, p. 15)	
Land claim	The main objective of land claim is neither erosion nor storm reduction. The aim of land claim is instead, to create new land from areas that were previously below high tide. However, if land	

Name	Definition	Parent measure
	claim is designed with the potential impacts of climate change in mind, measures can be taken to reduce the exposure of these areas to coastal flooding. Land claim is likely to be accomplished by enclosing or filling shore or nearshore areas. Several alternative terms may be used when referring to land claim; these may include land reclamation, reclamation fill and advance the line. (ClimateTechWiki, Land claim, accessed on Sept. 2016)	
Land use plan / spatial planning	Spatial planning systems are the methods used by the public sector to influence the distribution of people and activities in spaces of various scales, whereas land use plans govern/regulate the possibilities of construction on the territory of the municipality through definition of building codes and zoning ordinances (Nilsson K. and Rydén L., p.205). With increasing human alteration and development of the catchment area, the runoff generation process is changed, especially through decreasing the infiltration capacity of the soil and the change of soil cover. This has lead to concern over the role human alterations of the catchments play in increasing flood hazards. Urbanisation disrupts nature drainage patterns, natural watercourses are destroyed and the natural retention of runoff by plants and soil is removed. All structural flood management interventions need to be incorporated into the land use planning process to safeguard spatial requirements of those measures now and in the future in order to reduce flooding. Additionally, spatial planning reduces susceptibility to damage but having as requirement the availability of flood hazard maps that indicate the areas exposed to flooding for flood events of a given return period. Based on those maps different flood hazard zones can be delineated and placed under land-use regulation to limit the flood damage potential in those areas. Those regulations are tools to prescribe what uses are possible and under which conditions. Such conditions can also be put in place in terms of building regulations and codes. Further they can be used to prescribe adjustments to existing developments in those area, e.g. flood proofing or relocation of existing developments. Land use planning and regulation also plays a key role in balancing the development requirements and the preservation of the natural resources on flood plains. (World Meteorological Organization and the Global Water Partnership, 2008).	
Living with water - principles	The pursuit of a safe, healthy and sustainable water management is of national interest in the Netherlands. Themes like "water and the city", "water as co-planning principle" and “sustainable and resilient water system" are identified as priorities in the Dutch national policy. This is concluded in the two three-stage strategies for: Water quantity (delay, store, drain). Water quality (prevent, separate, treat) Realizing the goals and strategies of the national water policy is a joint task of the Dutch government, the provincial and municipal authorities and the water authorities, who are signed up to the National Administrative Agreement on Water (June 2008). The basic “living with water” principles of this agreement are: More room for water (“dry feet”); Stand-still situation: no further deterioration in chemical and ecological water quality from 2000 (“clean, healthy water”) and	

Name	Definition	Parent measure
	Preventing water problems being shifted to other areas and a later date. In addition, water in the Netherlands has its own place in the spatial decision-making process through the obligatory "Water Assessment" (part of the Planning Act). The process of the water assessment means that when making spatial plans the implications and opportunities for water and/ or planning are considered at an early stage.	
Maintenance of hydraulic structures of the storm drainage system	Set up regulations on maintenance of the hydraulic structures and drainage network infrastructures so that their maximum conveyance capacity will be unlimited. Regular maintenance of hydraulic structures, is another crucial part of flood control. (Wikipedia, Flood control, accessed on Sept. 2016)	
Managed realignment	Managed realignment or managed retreat allows an area that was not previously exposed to flooding by the sea to become flooded by removing coastal protection. This process is usually in low lying estuarine areas and almost always involves flooding of land that has at some point in the past been claimed from the sea (Wikipedia, Managed retreat, accessed on Sept. 2016). Coastal realignment is often part of a policy to provide more effective sea defences or restore wetlands (Collin P., 2011, p. 39).	
Monitoring and flood forecasting through partnerships	Organizing and recording partnerships between the various actors so that optimal responsiveness of the population can be produced in case of a warning of a flood event. Strong need in this area for understanding and agreeing on roles and responsibilities including communication with the public and between agencies. Information from fire events and other incidents can be very useful for training.	Flood forecasting and early warning
Multi-functional flood defences	Multifunctional Flood Defences (MFD) is a newly developed concept to optimize allocation of urban space rather than constructing stand-alone structures. MFDs are flood defences that combine the function of flood protection with other functions such as housing, recreation and leisure, commercial buildings, ecology, mobility and transport, underground infrastructure and they are functional parts of the urban or rural environment (Oderker M., 2013).	
Multi-layer safety as a central concept for flood protection	The central concept for the revised water safety policy is formed by 'multi-layer safety'. In this concept safety is assured through multiple layers. 1. The first layer is the prevention of floods through strong dikes, dunes and storm and flood water defenses (more robust and future-focused). Prevention remains the primary pillar of the policy. 2. The second layer is achieving sustainable town and country planning. Careful town planning (choice of location and land use issues) can limit the numbers affected and amount of damage if flooding does occur. As a result, the flood risk will play a bigger role in considerations and decisions relating to town and country planning. 3. The third layer is disaster management if a flood occurs. Good	

Name	Definition	Parent measure
	preparation is essential to be able to respond effectively to a flood disaster. Preparation will also help to limit the amount of damage and the numbers affected. (Urban Green Blue Grids, Multi-layer safety and water robust building, accessed on Sept. 2016)	
Multi-level capacity building	According to the UNDP, in the global context, capacity refers to the ability of individuals and institutions to make and implement decisions and perform functions in an effective, efficient and sustainable manner. At the individual level, capacity building refers to the process of changing attitudes and behaviours- imparting knowledge and developing skills while maximizing the benefits of participation, knowledge exchange and ownership. At the institutional level it focuses on the overall organizational performance and functioning capabilities, as well as the ability of an organization to adapt to change. It aims to develop the institution as a total system, including individuals groups and the organization itself. UNDP sees capacity development as the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time. One of the major challenges of the capacity building process is to overcome the "entrapment effect". This entrapment is reflected by a reluctance of the stakeholders towards involvement or towards new approaches that are unknown and require changes in the mindset and the lifestyle. (Coastal Wiki, The Capacity Building Concept, accessed on Sept. 2016)	Public awareness, information, education and communication
Municipal flood control plan	The municipal plan expresses the shared goals, objectives and priorities of a community and allows its members to work together for a specific goal e.g. flood control/protection, in coordination with nearby communities, the region and the state as a whole. (Vermont, Flood Ready State of Vermont, accessed on Sept. 2016). Its goal is to remove readiness barriers (e.g. lack of clarity about who is responsible, what elements of the planning and response processes are critical, how to coordinate with state and federal emergency management programs, and how to obtain and sustain funding, etc.) by providing all communities with strategies, processes, and tools for coordinated emergency management planning (Joint Commission, 2005). Creation of a municipal plan through which response guidance will be provided to the citizens in case of an extreme event occurs by assuring (ensuring) the alert, the information, the protection and the support of the population.	
Network of waterways	A network of waterways is mainly focused on connecting water bodies which are located near each other. By connecting them with culverts and canals, a larger water system is created. This increases the storage capacity of the system and thereby reduces the flood risk.	
Permeable paving	Permeable paving is a range of sustainable materials and techniques for permeable pavements with a base and sub base that allow the movement of water through the surface. It aims to	Increase of infiltration capacity

Name	Definition	Parent measure
	attenuate the surface runoff. In addition, this effectively traps suspended solids and filters pollutants in the soil. Besides pavements examples include roads, lawns and lots that are subject to light vehicular traffic, such as parking lots.(Wikipedia, Permeable paving, accessed on Sept. 2016)	
Polder	A polder is a low-lying tract of land enclosed by embankments (barriers) known as dikes that forms an artificial hydrological entity, meaning it has no connection with outside water other than through manually operated devices. During flood events those low lying areas are filled with water (Quizlet, Dikes and polders, accessed on Sept. 2016).	Flood detention reservoir
Pond	A pond is a body of standing water, either natural or artificial, that is usually smaller than a lake. They may arise naturally in floodplains as part of a river system, or they may be somewhat isolated depressions (Wikipedia, Pond, accessed on Sept. 2015). There are two types of ponds : detention ponds (dry ponds) or retention ponds (wet ponds) (Laramie County Conservation District, 2016). Detention ponds are a very common measure for flood mitigation as they are designed to detain the excessive runoff and then drain it completely after the end of the rainfall event. Basically, they are dry during the dry weather periods and wet during the wet weather periods. Their purpose is to detain excess flows which are exceeding the channel capacity (Vojinovic Z., Abbott M., 2012, p.466). Retention ponds are also commonly used for flood mitigation. As differentiated from detention ponds, retention ponds are designed to retain the water permanently. Excessive runoff is captured by these ponds and some portion is drained out after the end of the rainfall event. The water in these ponds is displaced and replaced in part by the stormwater (Vojinovic Z., 2015, p.102).	Increase of infiltration capacity
Port restructuring	Restructuring of the layout of the port, its equipment and flood protection system.	
Prescription on the construction code	Impose implementation of measures for mitigation and vulnerability reduction through the construction code of town planning. (ASFPM, Modifications to Existing Floodplain Structures, accessed on Sept. 2016).	Flood proof infrastructure
Public awareness, information, education and communication	Inform local citizens and visitors about the major hazards through public meetings, flyers, website, training, collaborative platforms, brochures, public presentations, internet portals, etc. Along with conventional methods for disseminating messages on flooding, in recent years frontline responders have started to use social media. Social media tools can provide a valuable resource to deliver up to date warnings and information to the public, media and even other responders. (International Federation of Red Cross and Red Crescent Societies, 2011)	
Pumping station	A pumping station is used to discharge water out of an area. It can be used to transport sewer water in pressure mains. Another option is to be used in polder systems to pump water from a low lying area into a main water body like a river or a lake. It is	Conventional urban drainage systems

Name	Definition	Parent measure
	always applied when no natural flow of water is possible. A flood control pumping station manages extremely large amounts of water flowing in open canals at low heads. This solution demands a good infrastructure because of the large inlet channels or pump sumps. Also, the power supply comes from a power plant, a dedicated power structure, or a combination of them. Additionally, by increasing the pump capacity of a pumping station water tables can be controlled better. Responding to heavy rains becomes easier, and the chance of flooding is reduced. The need for buffer capacity, translated into low water tables in rivers and channels, is also reduced as the managers have more pumping capacity. (Grundfos, Flood Control Pumping Stations US LOW web, accessed on Sept. 2016).	
Rain garden	A rain garden is a planted depression or a hole that allows rainwater runoff from impervious urban areas, like roofs, driveways, walkways, parking lots, and compacted lawn areas, the opportunity to be absorbed. This reduces rain runoff by allowing stormwater to soak into the ground (as opposed to flowing into storm drains and surface waters which causes erosion, water pollution, flooding, and diminished groundwater). (Wikipedia, Rain garden, accessed on Sept. 2016)	Bioretention area
Rainwater disconnection	Rainwater disconnection, i.e. the separation of the sewage system from the rainwater discharge system, is also a solution to prevent sewer flooding. In particular, the two systems can be dimensioned to fit their respective nominal discharges. Rainwater disconnection is a frequent strategy in Water Sensitive Urban Design (WSUD), and also part, in the U.S., of the LID (Low Impact Development) and Green Infrastructure initiatives. (Staub M. and Moreau-Le Golvan Y., 2012, p. 28)	
Rainwater harvesting system	The term rainwater harvesting refers to reuse of stored water, including water purification, and can form part of a sustainable drainage system. Although its main purpose is the increase of water supply in areas of water scarcity where the conventional water supply has failed to meet the demand of the community, rainwater harvesting has also been proven to be an important technique for flood mitigation. The “areal” approach of managing rainwater at source within a watershed, especially in urban areas, by collecting and then storing the water in numerous tanks and storage structures, can reduce peak runoff and help in reducing peak flow. Examples of equipment used as rainwater harvesting systems are rainwater tanks or barrels or cisterns which are used to collect and store rain water runoff, typically from rooftops via rain gutters (Jha A., et.al., 2011, p. 245).	
Rainwater storage beneath sports fields	One option for creating additional water storage facilities is storing in underground crates. This is a hidden technology that fits the criteria of sustainable urban planning. An interesting form of multiple uses of single spaces is realising water storage beneath sports fields. The technical aspects are simple to achieve using storage boxes/bulbs. Sports fields can be integrated into water systems in one of two ways. Firstly, the water storage facility is connected directly to surface water. In	Increase of infiltration capacity

Name	Definition	Parent measure
	this scenario, the water level below the sports fields rises according to the surface water level. This is a simple system to operationalise. Fluctuations in the water levels are limited by the maximum fluctuation of the surface water level. Secondly, the water storage facility is not connected directly to surface water. In this scenario, the water that needs storing is fed in from elsewhere, stored and drained at a delayed pace. This allows for more water to be stored, since greater fluctuations in water levels are possible. (Urban Green-Blue Grids for sustainable and resilient cities, Rainwater storage beneath sports fields, accessed on Sept. 2016)	
Raised kerb	Kerb or curb is the edge of the pavement at the side of the road. Water can be channeled along streets with raised kerbs and also to limit contact with buildings. For instance, this could reduce the probability for flood water to enter buildings. This way more water can be stored in the street profile without flooding the buildings (Wikipedia, Curb, accessed on Sept. 2016 & Design manua for roads and bridges, 2006).	
Red alert exercise	A red alert emergency exercise enables the simulation/testing of population/authorities response and plans in case of an extreme flood event occurs. Preparation of population is achieved for a crisis situations.	Flood emergency framework
Rescue plan	The aim of flood rescue operations is to move people from immediate or potential harm to safety. Failed evacuation operations (e.g. evacuation operations which have been initiated too late and have not been completed before egress routes are lost) can result in the need for large-scale coordinated rescue plans to take place to rescue people and animals from flood islands or inundated areas (Australian Institute for Disaster Resilience, 2009).	
Reserve funds	Building a catastrophic reserve fund is one of the measures assisting risk management as it will enable claims to be provided in years with unusually costly flood disasters. Many countries maintain a catastrophe reserve fund financed from tax revenues and invested in readily liquid assets. This financing option also spreads the costs among the taxpayers, but it differs importantly from a post-disaster tax. There is an additional cost equal to the foregone return from maintaining liquid funds and an additional benefit in having the funds immediately available. In principle, insurance companies also operate with a reserve to cover large outlays; however, private insurers are more concerned than the government that their reserves are sufficient to avoid insolvency. In the absence of a solvency constraint, the government can assess the comparative attractiveness of a catastrophe fund by weighing the costs of holding liquid reserves in comparison with the costs associated with hedging instruments (Kunreuther H. and Linnerooth-Bayer J., 2003, p. 632).	
Retention of rainwater in the vicinity of a	In case of an extreme event the surface runoff is conveyed by the streets to a roundabout, where it is temporarily stored and infiltrated into the ground. (Vojinovic Z., 2015, p.105)	Increased capacity of sewer/drainage system

Name	Definition	Parent measure
roundabout		
Revetment	Revetments are sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water. River or coastal revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion. (Wikipedia, Revetment, accessed on Sept. 2016). A revetment is a facing of stone, concrete units or slabs, etc., built to protect a scarp, the foot of a cliff or a dune, a dike or a seawall against erosion by wave action, storm surge and currents. This definition is very similar to the definition of a seawall, however a revetment does not protect against flooding. Furthermore, a revetment is often a supplement to other types of protection such as seawalls and dikes (Coastal Wiki, Revetment, accessed on Sept. 2016). Revetments can also be made of rock/boulders, gabions, articulating mattresses, sand containers or bio-engineering. The bio-engineering approach of slope protection or erosion protection is a nature friendly revetment structure by Vetiver plantation. A combination of cohesive soil and Vetiver grass provides the best protection against erosion, which implies that it is highly suitable for banks in delta areas, which consist pre-dominantly of cohesive soil. As such, the bio-engineering approach revetment for slope protection or erosion protection can be considered as green measures.	
Rip rap	Rip rap is large boulders of rock that are placed along the edge of the coastline and is sometimes referred to as rock armouring. They work by dissipating the wave's energy before it reaches the coastline, therefore the erosive power of the wave is greatly decreased. Rip rap can also be used to build other structures such as sea walls, revetments or groynes (Field Studies Council: Geography Fieldwork, Rip Rap, accessed on Sept. 2015).	Revetment
River Training	River training refers to the structural measures which are taken to improve a river and its banks. River training is an important component in the prevention and mitigation of flash floods and general flood control, as well as in other activities such as ensuring safe passage of a flood under a bridge. For flash flood mitigation, the main aim is to control the water discharge regime in the watercourse by limiting its dynamic energy, thereby controlling the morphological evolution of the watercourse. More specifically, the river channel may be deepened allowing it to carry more water. Involves the moving of mud and sand along a river course until the bends of the river are filled and its main channel is excavated sufficiently enough to contain the volume of water. Channel widening can rehabilitate regulated watercourses and reduce the extent of streamed erosion and the risk of flooding. Widening the river gives it the opportunity for self-dynamic development of a typical equilibrium. River training structures can be classified into two main categories: transversal protection structures and longitudinal protection structures (Shrestha, A. B. et. al., 2012, p. 60).	

Name	Definition	Parent measure
Safety margins in new investment	Uncertainties in climate change make it difficult to predict precisely the required degree of protection. Often, when it is cheap, it is sensible to add ‘security margins’ to design criteria, in order to improve the resilience of infrastructure to future (expected or unexpected) changes. This is also known as ‘conservative design’, and accounts for statistical uncertainty and unrecognised ignorance. (Staub M. and Moreau-Le Golvan Y., 2012, p.81)	Flood insurance
Sandbag wall	A sandbag is a bag or sack made of hessian / burlap, polypropylene or other materials, that is filled with sand or soil and it is used for flood defence. Sandbags may be used during emergencies when rivers threaten to overflow their banks, or when a levee or dike is damaged. They may also be used in non-emergency situations (or after an emergency) as a foundation for new levees or other water-control structures. Sandbags are the most common form of temporary flood defences (Wikipedia, Sandbag, accessed on Sept. 2016).	Floodwall
Seawall	Seawalls are hard engineered structures with a primary function to prevent further erosion of the shoreline. They are built parallel to the shore and aim to hold or prevent sliding of the soil, while providing protection from wave action. Although their primary function is erosion reduction, they have a secondary function as coastal flood defences. The physical form of these structures is highly variable; seawalls can be vertical or sloping and constructed from a wide variety of materials. They may also be referred to as revetments (Climatewiki, Seawalls, accessed on Sept. 2016).	Floodwall
Sectional barrier	These systems consist of multiple sections made of rigid materials such as steel or fibreglass which are joined or interlocked to form a continuous barrier. The barriers are fully preinstalled and only require operation during an emergency. Operation can be either manual or automatic. They are normally hidden away in an underground compartments or housings and once deployed attach to an adjacent structure or permanent protection. Sectional barriers can be automatic or manual (Ogunyoye F. et. al, 2011, p.54).	Floodwall
Sediment replenishment	Sediment replenishment method is one of new measures of sediment management mostly used in river systems where dams/reservoirs have been created. In this method, trapped (and most commonly coarse) sediment is periodically excavated (or dredged depending on the site conditions) and then transported and placed on an eroded area e.g. a channel downstream of a dam, in a manner decided according to the sediment transport capacity, the hydrodynamic conditions of the new sediment position and the environmental conditions. The replenishment processes are efficient to restore initial conditions and the bed load transport and to compensate sediment deficits that might occur in parts of rivers and floodplains after a flood event. (Schleiss A. and Boes R., 2011, p. 357)	

Name	Definition	Parent measure
Seepage barrier	Seepage barriers are constructed in order to control and mitigate the subsurface flow, or seepage of water. Depending on the method employed, they are constructed using soil and bentonite, cement and bentonite, concrete, still sheets, balanced stable cement grout, or chemical grout. The final permeability measuring achieved might be less than 10-5 cm/s. Several methods are available to form cut-off walls or barriers including steel sheet-piling, slurry trench walls, concrete diaphragm walls, bored pile walls, grout barriers, mix-in-place barriers, artificial ground freezing etc (European Union, European Commission, accessed on Sept. 2016).	
Sluice	A sluice is a gate used to control the rate of flow of water. It fulfills the function of a flood protection and hinterland drainage. In normal operation the sluice is closed and open in dependence of the sea side water level and the water level in the hinterland. During the flood of a tidal circle if the water level sea side of the sluice raises above the water level in the hinterland the sluices closes its gates. During the ebb of tidal circle if the water level sea side of the sluice fall below the water level in the hinterland the sluice open its gates. The water can flow from the hinterland to the sea. By closing the sluice mechanically in case of a storm surge it act as a flood protection. Over the decades the design changed from simple wooden sluices to masonry sluices which can also act as ship locks.	
Soakaway	Soakaways are square or circular excavations either filled with rubble or lined with brickwork, pre-cast concrete or polyethylene rings/perforated storage structures surrounded by granular backfill. They can be grouped and linked together to drain large areas including highways. The supporting structure and backfill can be substituted by modular or geocellular units (Susdrain, Soakaways, accessed on Sept. 2016). Soakaways are one type of "Infiltration Device", a simple way of dispersing surface and storm water in situations where connection to the sewer system system is impractical or unwarranted. The basic principle is that of a 'reverse well' i.e. a 'hole-in-the-ground' that loses water rather than collecting water. Installing a soakaway provides a means by which rainwater from a building can be collected and dispersed into the soil in a suitable location. (Paving expert, Soakways, accessed on Sept. 2016)	Increase of infiltration capacity
Social network mapping	Social network mapping can help stakeholders to locate their place within a wider network, and this network can be communicated and explained to others. It is a measure of social resilience among the communities because it helps transmit information and provide access to resources at critical time, especially during disaster events. The process of social network mapping can assess and visualize patterns of responsibility, power, and relationships among different authorities and actors responsible for natural hazard management, communication and coordination. Further, it captures linkages between the organizational network and the community. Social network mapping can be produced by "Sociograms" and "Organigrams". They are tools used for the visualisation of stakeholder	Public awareness, information, education and communication

Name	Definition	Parent measure
	categories, their interdepencies, information flos and other features of the stakeholders networks. Sociograms illustrate links among stakeholders, whereas organigrams how the categorisation of stakeholders and their inter-responsabilities regarding flood risk management. In the case of flood event, social network mapping helps to identify 1) what type of resources or support (e.g. physical, social, emotional, financial) is sought by actors communities before, during and after the flood; 2) which organisations or individuals are providing this support; 3) who are the central actors within specific social networks. (Matin N. et. al., 2015 & Vojinovic Z., 2015)	
Stilt house building	A stilt house is a raised structure that is most commonly built above water, although it also may be built over dirt or sand. It is sometimes called a pile dwelling because it is supported by large stakes, known as piles, that are driven directly into the water or into the shoreline. These structures typically rest 10 - 12 feet (3.5 - 4 meters) off the ground to allow for high tide, and are designed to avoid flooding and water damage. Created from bamboo or other water-resistant timber and reinforced with deck boards and sometimes concrete, stilt houses can be found throughout the world. The use of stilt house building technology effectively reduces flood or water-logging risk. For houses built along the river, cylinder stilts will produce much less resistance against water flow and thus are more stable. While for houses built in areas where water flow is slower, square stilts have the advantage of easy constructing (Quora, What is stilt house?, accessed on Sept. 2016).	Building elevation
Storm surge barrier	Storm surge barriers are hard engineered structures with a primary function of preventing coastal flooding. Their secondary role is to shorten the required length of defences behind the barrier. This reduces the risk of defence failure and reduces the cost of providing the additional defences. Surge barriers can be either movable or fixed. (Coastalwiki, Storm surge barriers and closure dams, accessed on Sept. 2016).	Floodwall
Stormwater harvesting system	Stormwater harvesting (SWH) consists in collecting, storing and reusing stormwater collected from drains or creeks, on the contrary to rainwater harvesting (RWH), where rainwater is directly collected from roofs. SWH is particularly common in Australia and New Zealand, while almost unknown in many other countries where RWH is preferred. (Staub M. and Moreau-Le Golvan Y., 2012, p. 48)	
Stormwater retention tank	Stormwater tanks are an effective way of reducing peak flow and equalising flow rates from storm water runoffs in the sewer system. Placed strategically, stormwater tanks mean better utilisation of the existing sewer system, allow for intelligent management of storm water flows, and ultimately save on	Stormwater harvesting system

Name	Definition	Parent measure
	infrastructure investments. Stormwater tanks can be relatively easily adapted to the sewer system, and during heavy rain the sewer system is relieved by guiding excess storm water to the stormwater tank for temporary storage. (GRUNDFOS, Design of StormWater Tanks, accessed on Sept. 2016)	
Sunken lane	A sunken lane (also hollow way or holloway) is a road or track which is significantly lower than the land on either side, not formed by the (recent) engineering of a road cutting but possibly of much greater age. Various mechanisms have been proposed for how holloways may have been formed, including erosion by water or traffic; the digging of embankments to assist with the herding of livestock; and the digging of double banks to mark the boundaries of estates. (Wikipedia, Sunken lane, accessed on Sept. 2016). Once formed, hollow-ways often remain in use for long periods and become drainage gullies for surface water, which deepens them further. (Historic England, Pre-industrial Roads, Trackways and Canals, accessed on Sept. 2016).	Increase of infiltration capacity
Swale	A swale is a low tract of land, especially one that is moist or marshy. The term can refer to a natural landscape feature or a human-created one. Artificial swales are often designed to collect water runoff, and increase rainwater infiltration, therefore reduce runoff. They can be covered by grass or other vegetation and have shallow side slopes and a flat bottom which means that for most of the time the water flows in a thin layer through the grass or other vegetation. Three main types of swales can be defined according to Kellagher (2005). Larger swales with a focus on rainfall runoff attenuation are mostly situated besides roads or parking places with a depth of about 0.4m, a width of about 5m at ground level and 1m at the bottom level. Smaller swales, so called "mini-swales", could be designed with a width of about 1m and a depth of 0.1m which are used to receive rainwater runoff, store it for infiltration and drain the runoff into the drainage once it is full. (Wikipedia, Swale, accessed on Sept. 2016)	Increase of infiltration capacity
Tax relief	After a disaster, the government can raise funds for disaster rehabilitation with a tax. Like hedging instruments, a tax spreads the costs of the disaster response across the general public (Kunreuther H. C. and Linnerooth-Bayer J., 1999, p. 14). Tax relief is intended to reduce the tax liability of an individual or business entity. Often, the tax relief is targeted at providing aid for a certain event or cause. For example, hurricane victims may be allotted some form of tax relief when a hard-hit area is declared a disaster area (Investopedia, Tax relief, accessed on Sept. 2016).	
Toroba	Toroba is a homemade diversion structure that is used to divert flood water for water supply augmentation. It is built of wooden poles, taken from trees such as the curari and cuji in Venezuela, vegetation residues, and logs. The wooden poles are 50 and 130 cm in length and are placed at intervals of 50 cm to 70 cm to define a wall of debris that will divert the runoff (UNEP -	

Name	Definition	Parent measure
	International Environmental Technology Centre, 1997).	
Tubes	Tubes (air filled or water filled) flood protection products are typically pre-fabricated geo-membrane or reinforced PVC tubes filled with air or water to form a dam. They utilise air or water, usually in abundance during flood events. Tubes are another example of temporary flood protection systems. (Ogunyoye F. et. al., 2011, p. 38)	
Unused sewers	Many towns and cities have large numbers of unused sewers. It is often too expensive to remove them. Giving those unused sewers a second life for retaining precipitation may be a simple option for realising a precipitation reservoir in an existing situation (Urban Green-Blue Grids for sustainable and resilient cities, accessed on Sept. 2016).	Increased capacity of sewer/drainage system
Urban forest and park	An urban forest is a forest or a collection of trees that grow within a city, town or a suburb. In a wider sense it may include any kind of woody plant vegetation growing in and around human settlements. Cities can use parks to reduce public costs for stormwater management, flood control, transportation, and other forms of built infrastructure (Wikipedia, Urban forest, accessed on Sept. 2016).	
Vulnerability assessment	Vulnerability assessment is important in to consider in risk management and flood damage assessment. Researches with vulnerability subject involves diverse descriptions for vulnerability; in United Nations' description vulnerability is a degree of damage to a certain objects at flood risk with specified amount and present in a scale from 0 to 1 (no damage to full damage) (United nations 1982). The vulnerability refers mainly to the flood prone area characteristics related to the potential of damage and to the local recovery capacity. Creation of an observatory of vulnerability and its evolution through time assists further in resilience enchancement. (Nasiri H. et. al., 2016 & Cançado V. et. al., 2008)	
Water square	The water square combines water storage with the improvement of the quality of urban public space. It makes money invested in water storage facilities visible and enjoyable. When heavy rains occur, rainwater that is collected from the neighbourhood will flow visibly and audibly into the water square. Short cloudbursts will only fill parts of the square. When the rain continues, more and more parts of the water square will gradually be filled with water. The rainwater will be held in the square until the water system in the city has enough capacity again. Then the water can run off to the nearest open water. (De Urbanisten, Water squares, accessed on Sept. 2016)	Multi-functional flood defences
Weir	A weir is a barrier across a river designed to alter the flow characteristics. In most cases weirs take the form of obstructions smaller than most conventional dams, pooling water behind them while also allowing it to flow steadily over their tops. Weirs are commonly used to alter the flow of rivers to prevent flooding, measure discharge, and help render rivers navigable. In some places the crest of an overflow spillway on a large dam may also	Sectional barrier

Name	Definition	Parent measure
	be called a weir. Weirs can vary in size both horizontally and vertically, with the smallest being only a few inches in height whilst the largest may be hundreds of metres long and many metres tall. Unlike a dam, which has the specific purpose of impounding water, a weirs purpose can be less obvious and they most commonly are used to alter or control the flow characteristics of the river. A particular distinction between dams and weirs is that a weir has water flowing over the top (crest) of the structure along at least some of its length. Some of the most common weir types are labyrinth weir, broad-crested weir, sharp crested weir, piano keys weir, compound weir and V-notch weir. (Wikipedia, Weir, accessed on Sept. 2016)	
Wet-floodproofing technology	Wet-floodproofing can be an appropriate approach to improve the flood resilience of new and existing buildings, particularly in areas at high flood risk. Wet-floodproofing is defined as a strategy that permits water to enter a property rather than dry-proofing which prevents ingress. Hence, the principle intention of wet-proofing is to change the design and/or the material of potentially affected building constructions in order to mitigate their flood vulnerability and to minimise the extent of necessary repair works after a flood. Wet-floodproofing comprises the application of improved materials for layers of flood-prone wall, ceiling and floor constructions, which are less susceptible to flood damage.	
Wetland and wetland restoration	A wetland (Natural or Constructed/Artificial) is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem. Primarily, the factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants, adapted to its unique hydric soil (Wikipedia, Wetland, accessed on Sept. 2016). Constructed wetlands are man-made systems, designed and constructed using the natural processes typical of natural wetlands. These natural processes are an interaction and combination of wetland plants, soil and microbial life. Knowledge of these natural processes is used to control the operation and efficiency of the constructed wetlands (Constructed Wetlands, accessed on Sept. 2016). Constructed wetlands are primarily used for the control of urban runoff as well as for water quality improvements. They are typically designed to have a short residence time in order to prevent mosquito breeding. Wetland restoration can serve to reduce coastal flooding and erosion and can also provide new habitats and environmental benefits. Wetland restoration relates to the rehabilitation of previously existing wetland functions from a more impaired to a less impaired or unimpaired state of overall function. Although similar to managed realignment, wetland restoration can be distinguished by the goal to maintain the present position of the coastline as opposed to realigning landward, as occurs under managed realignment (Climatetechwiki, Wetland restoration, accessed on Sept. 2016).	Bioretention area

Name	Definition	Parent measure
Wharf	Wharf is the oldest term in English referring to port structures. It denotes any structure of timber, masonry, cement, or other material built along or at an angle to the navigable waterway, with sufficient depth of water to accommodate vessels and receive and discharge cargo or passengers. The term can be substituted for quay when applied to great solid structures in large ports. The area between the quay wall (made of solid masonry) and the nearby warehouse or storage facility is called the quay apron. (Ports and Harbours, p. 5) A quay (or wharf) can be a good flood protection in locations where available space is limited. Quays are mostly reinforced concrete structures.	

Annex 4 – List of Case Studies

The full list of case studies (Applications of resilience measures) with links to detail pages is provided online under the following URL:

http://pearl-kb.hydro.ntua.gr/l/Application/

Name of case study	Country/ Countries	Application type	Applied resilience measures
Adjustment of fairway, Lühe and Stadersand, Lower Saxony (20th c.)	Germany	Real Case Study	Adjustment of fairway
Adjustment of fairway, Lühe, Lower Saxony(20th c.)	Germany	Real Case Study	Adjustment of fairway
Adjustment of fairway, Stadersand, Lower Saxony (20th c.)	Germany	Real Case Study	Adjustment of fairway
Afforestation, Ancient Olympia, Ileia	Greece	Real Case Study	Afforestation
Afforestation, North Rhine-Westphalia	Germany	Real Case Study	Afforestation
Aquifer recharge, Maldives	Maldives	Real Case Study	Aquifer recharge | Vulnerability assessment
Aquifer recharge, Paso del Norte, Texas	United States of America	Modelled/Simulated Case Study	Aquifer recharge
Aquifer recharge, Veurne Region	Belgium	Real Case Study	Aquifer recharge
Artificial sand dunes and dune rehalibitation, Les Boucholeurs	France	Real Case Study	Artificial sand dunes and dune rehabilitation
Awareness raising, Les Boucholeurs	France	Real Case Study	Public awareness, information, education and communication
Beach nourishment, Les Boucholeurs	France	Real Case Study	Beach nourishment
Bluebelt Project, New York	United States of America	Real Case Study	Wetland and wetland restoration
Building elevation, Hafencity, Hamburg	Germany	Real Case Study	Building elevation
Building of 60 polders in the port area (private flood protection), Hamburg (20th c.)	Germany	Real Case Study	Polder

Name of case study	Country/ Countries	Application type	Applied resilience measures
Bypass channel, Bisagno River, Genoa	Italy	Real Case Study	Bypass channel
Channel adjustments, Freiburger Watt, Lower Saxony (20th c.)	Germany	Real Case Study	Adjustment of fairway
Climate Adaptation Plan, Greve	Denmark	Other	Vulnerability assessment | Municipal flood control plan
Climate Change Adaptation, Greve	Denmark	Real Case Study	Managed realignment | Increased capacity of sewer/drainage system | Pumping station | Dike
Combination of measures, Saulxures and Pulnoy, Nancy	France	Real Case Study	Wetland and wetland restoration | Urban forest and park | Water square
Combined Measures, Acharnai, Attica	Greece	Real Case Study	Permeable paving | Stormwater retention tank
Combined measures, Karlstrup Mose, Denmark	Denmark	Real Case Study	Managed realignment | Network of waterways | Flexible water level management | Flood detention reservoir
Combined measures, Schleswig-Holstein, Seestermüher Marsch (20th c.)	Germany	Real Case Study	Dike | Floodwall
Combined sewer overflow, Helsingborg	Sweden	Modelled/Simulated Case Study	Flood hazard mapping
Construction of dike, Groden (Hadeln), Lower Saxony (20th c.)	Germany	Real Case Study	Dike
Construction of dikes and flood barrier, Wedeler Au, Schleswig-Holstein (20th c.)	Germany	Real Case Study	Dike | Floodwall
Construction of flood barrier, Billwerder bay, Hamburg (20th c.)	Germany	Real Case Study	Floodwall
Construction of flood barrier, Freiburger Hafenpriel, Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall
Construction of flood gate, pumping station and dike wall, Hoopte, Lower Saxony (20th c.)	Germany	Real Case Study	Dike | Flood gate
Construction of flood protection walls and sluice, Cuxhaven, Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall | Sluice

Name of case study	Country/ Countries	Application type	Applied resilience measures
Construction of lood barrier, Ilmenau, Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall
Construction of pumping station with sluice and two weirs, Kuckuckshorn/Wilhelmsburg, Hamburg (20th c.)	Germany	Real Case Study	Sluice | Pumping station | Weir
Construction of Seeve flood barrier, Wuhlenburg, Lower Saxony (20th c.)	Germany	Real Case Study	Dike reinforcement
Construction of sluice and pumping station, Alsterfleet, Hamburg (20th c.)	Germany	Real Case Study	Sluice | Pumping station
Construction of sluice and pumping station, Bullenhausen, Lower Saxony (20th c.)	Germany	Real Case Study	Pumping station | Sluice
Construction of storm surge/flood barrier, Lühe, Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall
Construction of the Elbe weir, Geesthacht , Schleswig- Holstein (20th c.)	Germany	Real Case Study	Weir
Construction of Trischendamms, Friedrichskoog, Schleswig- Holstein, (20th c.)	Germany	Real Case Study	Dike
Continuous deepening of the tidal Elbe to 13,5m under MTnw with time, Tideelbe, Hamburg, Schleswig- Holstein, Lower Saxony (20th c.)	Germany	Real Case Study	River Training
Conventional urban drainage systems, Marbella	Spain	Modelled/Simulated Case Study	Conventional urban drainage systems
Dam, Hanskalbsand and Neßsand (20th c.)	Germany	Real Case Study	Dike
Damming by flood barrier, Wischhafener Süderelbe, Lower Saxony, (20th c.)	Germany	Real Case Study	Flood control dam
Demountable flood protection barrier, Marbella	Spain	Modelled/Simulated Case Study	Demountable flood protection barrier
Detention basin, Marbella	Spain	Modelled/Simulated Case Study	Flood detention reservoir
Detention basin, South-East England	United Kingdom	Real Case Study	Flood detention reservoir
Dike construction, Cranz, Hamburg (20th c.)	Germany	Real Case Study	Dike
Dike construction, Glücksatdt Nord (20th c.)	Germany	Real Case Study	Dike

Name of case study	Country/ Countries	Application type	Applied resilience measures
Dike construction, Twielenfleth, Lower Saxony (20th c.)	Germany	Real Case Study	Dike
Dike inspection and reinforcement, North Sea coast, Lower Saxony (20th c.)	Germany	Real Case Study	Dike reinforcement | Dike inspection and/or recovery
Dike reinforcement, Land Hadeln, Lower Saxony, (20th c.)	Germany	Real Case Study	Dike reinforcement
Dike relocation, Rhine river basin	Germany | Netherlands	Real Case Study	Dike
Dike, Bützflether Sand, Lower Saxony (20th c.)	Germany	Real Case Study	Dike
Dike, Les Boucholeurs	France	Real Case Study	Dike
Dry-proofing, New York	United States of America	Real Case Study	Dry-floodproofing technology | Flood gate
Dual reservoir function, New York	United States of America	Real Case Study	Flood control dam
Dual use of recreational and flood control measures, Ceres, California	United States of America	Real Case Study	Urban forest and park | Water square
Dwelling mound concept, Hafen City, Hamburg (21st c.)	Germany	Real Case Study	Dwelling mound
Emergency Operation Centre, Marbella	Spain	Real Case Study	Emergency operation centre and personnel | Public awareness, information, education and communication | Flood forecasting and early warning
Excavations of Schwarztonnensand, Hamburg (20th c.)	Germany	Real Case Study	River Training
Expansion of Rhinplatte Inseln, Rhinplatte (20th c.)	Germany	Real Case Study	Hydraulic filling
Fairway adjustment, Elbe river, Schleswig-Holstein, Lower Saxony(20th c.)	Germany	Real Case Study	Adjustment of fairway
Floating houses, Maasbommel	Netherlands	Real Case Study	Floating building | Amphibious building

Name of case study	Country/ Countries	Application type	Applied resilience measures
Flood barrier and dike, Stör, Schleswig-Holstein (20th c.)	Germany	Real Case Study	Dike | Floodwall
Flood barrier, Este, Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall | Adjustment of fairway
Flood barrier, Lühe, Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall
Flood barrier, Oste, Otterndorf, Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall
Flood barrier, Schwinge (Stade), Lower Saxony (20th c.)	Germany	Real Case Study	Floodwall
Flood barriers, Nikolaifleet and Herrengrabenfleet, Hamburg (20th c.)	Germany	Real Case Study	Floodwall
Flood control dam, Kamaraki stream, Rethymno	Greece	Real Case Study	Flood control dam
Flood control dam, Rapentosa, Attica	Greece	Real Case Study	Flood control dam
Flood forecasting and Early warning, Les Boucholeurs	France	Real Case Study	Flood forecasting and early warning
Flood forecasting and early warning, Marbella	Spain	Real Case Study	Flood forecasting and early warning
Flood forecasting and early warning, Marbella	Spain	Real Case Study	Flood forecasting and early warning
Flood gate, Prague	Czech Republic	Real Case Study	Flood gate | Check valve
Flood hazard mapping, Manila, Ho-Chi-Minh, Bangkok	Philippines | Thailand	Real Case Study	Vulnerability assessment | Flood hazard mapping
Flood hazard mapping, Marbella	Spain	Real Case Study	Flood hazard mapping
Flood Insurance, GDV	Germany	Real Case Study	Flood insurance
Flood insurance initiatives	Germany | United Kingdom	Real Case Study	Flood insurance
Flood insurance, USA	United States of America	Other	Flood insurance
Flood protection system, St. Pauli Fischmarkt, Hamburg (20th c.)	Germany	Real Case Study	Floodwall

Name of case study	Country/ Countries	Application type	Applied resilience measures
General plan - dike reinforcement, dike shortening and coastal protection,Marshland, Schleswig-Holstein (20th c.)	Germany	Real Case Study	Municipal flood control plan
Green roofs, Vesterbro, Copenhagen	Denmark	Real Case Study	Green roof
Green wall, London	United Kingdom	Real Case Study	Green wall
Groin, Les Boucholeurs	France	Real Case Study	Groyne
High water flood mark, Les Boucholeurs	France	Real Case Study	High water mark
Hydraulic filling of islands, Tidal Elbe, (20th c.)	Germany	Real Case Study	Hydraulic filling
Hydraulic fillings: Hollerwettern-Scheelenkuhlen, Vorland Glückstadt, Fährmannssand, Hanskalbsand until Neßsand, Hetlinger Schanze, Bützflether Sand, Schwarztonnensand, Pagensand and Giesensand (20th c.)	Germany	Real Case Study	Hydraulic filling
Increase capacity of sewer/drainage system, Berlin	Germany	Real Case Study	Increased capacity of sewer/drainage system
Increased capacity of sewer/drainage system, Marbella	Spain	Modelled/Simulated Case Study	Increased capacity of sewer/drainage system
Increased capacity of sewer/drainage system, Paris	France	Real Case Study	Increased capacity of sewer/drainage system
Increased capacity of sewer/drainage system, Thames, London	United Kingdom	Real Case Study	Increased capacity of sewer/drainage system
Land use plan, Les Boucholeurs	France	Real Case Study	Land use plan / spatial planning
Les Boucholeurs 4	France	Real Case Study	Family emergency planning
Maintenance of hydraulic structures of the storm drainage system, Les Boucholeurs	France	Real Case Study	Maintenance of hydraulic structures of the storm drainage system
Management of water level of swamps, Les Boucholeurs	France	Real Case Study	Flexible water level management
Multi-functional flood defences, De Stadswerven and Westflank, Dordrecht	Netherlands	Real Case Study	Multi-functional flood defences

Name of case study	Country/ Countries	Application type	Applied resilience measures
Observatory of exposure and vulnerability, Les Boucholeurs	France	Real Case Study	Vulnerability assessment
Part backfilling and Port restructuring, Mühlenberger Loch, Hamburg (21st c.)	Germany	Real Case Study	Land claim | Port restructuring
Re-building of the Bisagno cover, Genoa	Italy	Real Case Study	Floodplain excavation
Red alert exercise and Protection plan, Les Boucholeurs	France	Real Case Study	Municipal flood control plan | Red alert exercise
Redesign of flood protection system, Hamburg (20th c.)	Germany	Real Case Study	Dike inspection and/or recovery
Redesign of flood protection system, Hamburg (21st c.)	Germany	Real Case Study	Dike
Redesigned flood protection system, Hamburg Port (20th c.)	Germany	Real Case Study	Flood hazard mapping
Regulation of Grevebækken, Greve Landsby	Denmark	Real Case Study	Flood detention reservoir | Managed realignment | Increased capacity of sewer/drainage system
Relocation of dike, Alte Süderelbe, Hamburg (20th c.)	Germany	Real Case Study	Dike
Relocation of dike, Hahnhöfer Sand, Hamburg (20th c.)	Germany	Real Case Study	Creation of a second dike line
Relocation of dike, Nordkehding, Lower Saxony (20th c.)	Germany	Real Case Study	Dike relocation
Relocation of dikes, Krautsand and Asseler Sand, Lower Saxony (20th c.)	Germany	Real Case Study	Dike relocation
Rotterdam Water City 2035, Rotterdam	Netherlands	Real Case Study	Dike | Green roof | Water square | Floating building
Safety margins in new investment, River Neckar, Baden-Württemberg	Germany	Real Case Study	Safety margins in new investment
Safety margins in new investment, San Diego	United States of America	Modelled/Simulated Case Study	Safety margins in new investment
Shore replenishment, Schleswig-Holstein (20th c.)	Germany	Real Case Study	Sediment replenishment

Name of case study	Country/ Countries	Application type	Applied resilience measures
Shore replenishment, Siebenhöfen, Lower Saxony	Germany	Real Case Study	Sediment replenishment
Sluice, Gose and Dove Elbe, Hamburg (20th c.)	Germany	Real Case Study	Sluice
Smart Flow, Reiderland	Netherlands	Real Case Study	Increased capacity of sewer/drainage system
Storm tide sluice, Friedrichskoog, Schleswig- Holstein (20th c.)	Germany	Real Case Study	Sluice
Stormwater harvesting, Australia	Australia	Real Case Study	Stormwater harvesting system
Sustainable urban drainage systems, Marbella	Spain	Modelled/Simulated Case Study	Permeable paving | Increase of infiltration capacity | Green roof
Tidal Elbe concept, Spadenlander Busch, Kreetsand (21st c.)	Germany	Real Case Study	Polder | Wetland and wetland restoration | Dike relocation
Vulnerability assessment of people and properties on territory, Les Boucholeurs	France	Real Case Study	Vulnerability assessment
Vulnerability assessment, Terceira Island	Portugal	Modelled/Simulated Case Study	Vulnerability assessment
Vulnerability Assessment, Zealand	Denmark	Modelled/Simulated Case Study	Vulnerability assessment
Wetland restoration, Danube Delta	Hungary | Romania	Real Case Study	Wetland and wetland restoration