The QGIS Plug-in

FloodRisk ver.1.0

USER MANUAL

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1. The QGIS Plugin *FloodRisk* v.1.0

The *Floodrisk* Plugin can be used to calculate the flood consequences in terms of direct economic damages and loss of lives. This first version of the plugin performs a simple and expeditious risk assessment in which fixed event scenarios have been considered. The probability of each scenario is estimated separately and consequences are calculated deterministically.

2. *FloodRisk* Aims and Scope

The plugin is conceived and developed by a (virtual) union of research centres, universities and SMEs, called ***FloodRiskGroup*** (https://github.com/FloodRiskGroup/floodrisk/blob/master/AUTHORS.rst) that collaborate close with territorial authorities and stakeholders in order to pursue the spread of scientific research with an Open, Free and repeatable approach in the field of water resource management.

These agencies and the individual software developers of *FloodRisk* take no responsibility for the correctness of outputs from *FloodRisk* or decisions derived as a consequence.

The *FloodRisk* plugin organizes part of the available knowledge and characteristics of the flood risk analysis methods available in the scientific literature in order to realize an operational tool for flood risk management.

The *FloodRisk* Plugin is the first attempt to realize collaborative, comprehensive, context-specific and applicable standards for flood risk analysis and to communicate flood risk worldwide thanks to the widespread QGIS platform.

Hence, we aim to build a shared and collaborative model through a community based approach where anyone can contribute with their own methods and formulas on testing the platform or translating its GUI in several languages. For more information, please, contact FloodRiskGroup@rse-web.it

The *FloodRisk* tool is developed in Python script language and is completely licensed GPL v.2 and available at https://github.com/FloodRiskGroup/floodrisk. *Github* is an open source platform where the developers can store their projects and can see, access and modify the work of others, in this way allowing projects to grow: it hosts open source software projects and has collaboration features.

3. How does *FloodRisk* work?

A generalized procedure/model for risk analysis should perform several damage assessments for events with different probabilities taking into account structural and non-structural mitigation measures. Clearly, risk quantification depends on spatial specifications (e.g., area of interest, spatial resolution of data) and relies on an appropriate scale of the flood hazard and land-use/buildings maps [1].

Therefore, the *FloodRisk* plug-in uses the powerful functions of QGIS to manage spatial information, providing adequate spatial processing, and visualization of results. The *FloodRisk* plugin requires as input the analysis of the extent and distribution of intensity of the flood hazard (i.e. flood extend and duration, water depth and velocity) that could be overlapped on the spatial distribution of exposed people and properties for the estimation of potential flood direct damage [2]. The direct flood impact can be subdivided in tangible and intangible (non-market) damage. On one hand, the direct tangible damage covers, for example, damage to structures and contents, destruction of infrastructure such as roads, rail roads. On the other hand, the evaluation of the direct intangible (non-market) damage can describe, for example, the estimation of loss of life [3].

The *FloodRisk* plugin uses depth–damage curves, which describe the monetary flood loss as a function of the type or use of the building and the inundation depth, in order to estimate the loss as a percentage of the structure or content value that are multiplied by the maximum damage value of properties for estimation of the economic damages. The plugin provides several maximum damage values and damage curves, based on economic sectors, but also gives the possibility to add user-custom values and curves.

Moreover, according to the review of relevant scientific literature (e.g. [4], [5], [6]), the *FloodRisk* plugin uses various factors, called “flood mortality” or “fatality rate”, that influence the loss of life caused by a given flood type to express mortality of population at risk. The *FloodRisk* plugin uses simple and parsimonious methods, based on several generally available contributing factors, for the estimation of potential loss of life. In particular, the *FloodRisk* plugin uses the value of contributing factors proposed in [7] and [8]: hazard factors, (such as water depth and water velocity), the degree of general preparedness of the society, (estimated taking into account the existence of public education on flood risk, the existence of warning and communication system, the coordination between emergency agencies and authorities, the time of day), and warning factors, (e.g. warning time).

The *FloodRisk* plugin can be used to support several stakeholders in the identification of people and assets at risk, the planning and evaluation of effective flood mitigation and emergency measures, the creation of flood risk maps for awareness raising.

4. Dataset

An example Data Set is available on *Github* at https://github.com/FloodRiskGroup/floodrisk-doc.
The key data required by FloodRisk concern: **hazard**, **receptor** and their **vulnerability**.
While the data on the hazard are stored simply in the computer file system, the receptor and vulnerability data are organized into a geodatabase.
By this way the database is the container of the characteristics of a given geographical area and can be used to calculate the consequences of several possible hazard scenarios with different probability. For example, you can create a new *FloodRisk* project for each hazard scenario, in which the corresponding hazard characteristics are assigned, and use the same exposure data, stored in the geodatabase, for evaluating the outcomes of the several simulation runs through a cost-benefit approach.

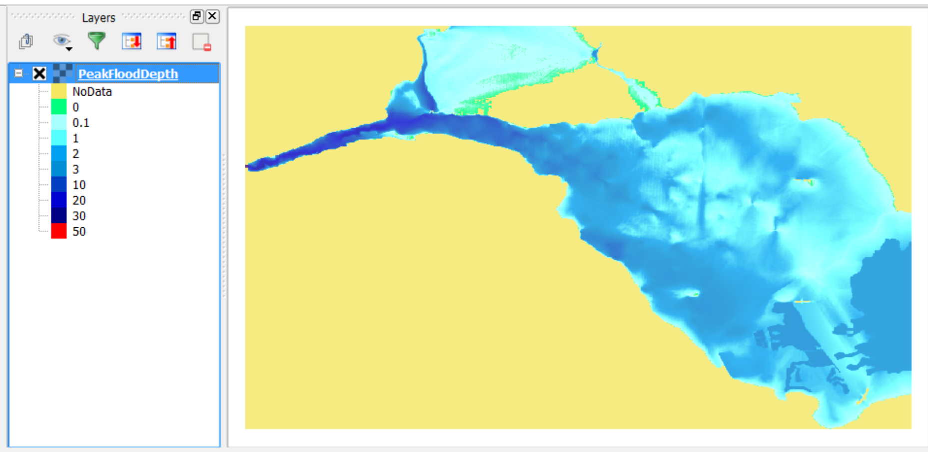
4.1 Hazard data

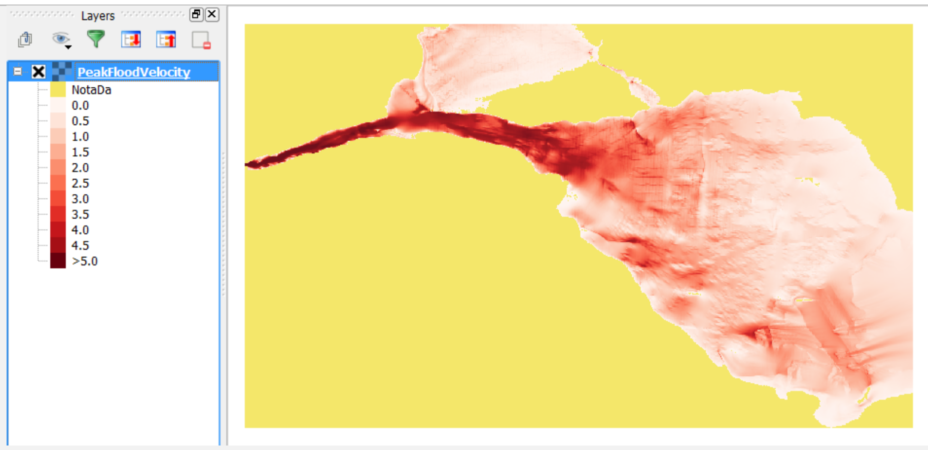
The hazard is evaluated by the use of the inundation map in which are detailed the characteristics of the flood. The *FloodRisk* plug-in requires specifically the maps of:

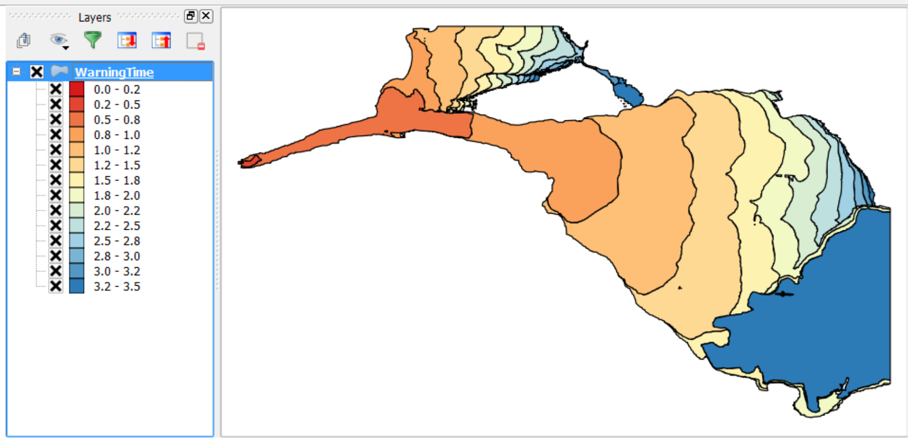
- Maximum water depth values;
- maximum water velocity values;
- warning time.

These hazard data can be estimated separately through one of the standard 2D hydraulic models on the market (e.g. MIKE FLOOD, Telemac2D, CCHE2D, HEC-RAS 2D). A 2D model performs calculations and provides the results of a 2D spatial domain. Whatever the model used, a GIS system can spatially report these results on a regular grid cells. Outputs generated from a 2D hydraulic model, therefore, include maximum depth and maximum velocity values for every inundated grid cell in the study area.
The *FloodRisk* input data file of the maximum water depth can be any raster (regular grid) files readable by gdal libraries (e.g. Arc/Info ASCII Grid, GeoTIFF File Format, and so on; see http://www.gdal.org/formats_list.html to check the complete list of supported raster format).
The warning time indicates the amount of time between the reception of a warning and the instant in which the population of each structure could be affected by the flood event, i.e. the amount of time in which the population of each structure can mobilize or adopt mitigation measurements. In case there isn't a flood forecasting system, we might suppose that the alarm occurs only after that an overflow of water from water bodies occurs. In this case, the warning time is approximately equal to the propagation time of the flood in the areas of land adjacent to a stream or river and this time can be calculated using the 2D hydraulic model. Instead, in case a flood forecasting system is available, the warning time is equal to the sum of the propagation time and the forecast time. Because the hydraulic model can provide the map as raster and, instead, the forecast time are added on the basis of user knowledge, we choose to utilize a vector map and, therefore, the user should upload it in the *FloodRisk* plug-in as a *shapefile* (e.g. in QGIS the

“Raster Conversion -> Polygonize” tool can help to solve this issues): it is more easy the editing of fields and updating of its value in a vector file.
Below a detailed description of the example dataset.

File name	**PeakFloodDepth.tif**
Geometry	GeoTIFF
Dimensions	X: 1593 Y: 961 Bands: 1
Data Type	Float32 - Thirty two bit floating point
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/PeakFloodDepth.tif
Description	Maximum water depth due to flood
Preview image	

File name	**PeakFloodVelocity.tif**
Geometry	GeoTIFF
Dimensions	X: 1593 Y: 961 Bands: 1
Data Type	Float32 - Thirty two bit floating point
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/PeakFloodVelocity.tif
Description	Maximum water velocity due to flood
Preview image	

File name	**WarningTime.shp**
Geometry	Polygon
The number of fields	1
Name of field	TimeHours
Data Type	real
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/WarningTime.shp
Description	Warning time in hours for each area defined by a polygon
Preview image	

4.2 Vulnerability data

Vulnerability is a characteristic of a system that describes its potential to be harmed. The vulnerability data utilized in the *FloodRisk* plug-in are alphanumeric tables stored in the *SpatiaLite* geodatabase. These alphanumeric data can be loaded into the geodatabase from csv files having semicolon as value separator and can be loaded through the **Database Manager** window (Fig. 1 and 5).

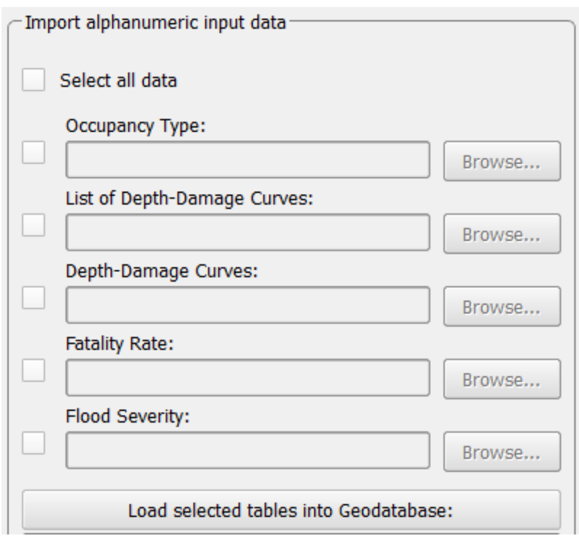


Figure 1 - Box of the Database Manager window for upload the alphanumeric input data.

4.2.1 Occupancy Type: is the list of codes of the types of goods and its own description. This data is stored in the database in the Domains table with NumDomain = 10. Below an example of a csv file where also the unit value of the asset is added.

File name	**OccupancyType.csv**
The number of fields	6
Name of field	IND; NumDomain; code; Description; Valstr; Valcon
Data Type	Integer; Integer; Varchar (15); Varchar (150); Real; Real
Source	FloodRiskData
URL example file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Tables/OccupancyType.csv
Description	List of codes of the types of goods and its own description Required data are: - code : alphanumeric code (max 5 char) - Description : alphanumeric description (max 150 char) - NumDomain = 10 Optional data are: - Valstr: unit value of the structure (Euro/m^2) - Valcon: unit value of the content (Euro/m^2)
Preview image	IND;NumDomain;code;Description;Valstr;Valcon 1;10;11100;Continuous Urban Fabric (S.L. > 80%);1520;760 2;10;11210;Discontinuous Dense Urban Fabric (S.L. : 50% - 80%);650;325 3;10;11220;Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%);400;200 4;10;11230;Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%);200;100 5;10;11240;Discontinuous Very Low Density Urban Fabric (S.L. < 10%);100;50 6;10;11300;Isolated Structures;25;37.5 7;10;12100;Industrial, commercial, public, military and private units;560;1960 8;10;12210;Fast transit roads and associated land;2600;104 9;10;12220;Other roads and associated land;1550;62 10;10;12230;Railways and associated land;9270;463.5 11;10;12300;Port areas;10300;515 12;10;12400;Airports;10300;515 13;10;13100;Mineral extraction and dump sites;0;0 14;10;13300;Construction sites;0;1 15;10;13400;Land without current use;0;0 16;10;14100;Green urban areas;0;0.2 17;10;14200;Sports and leisure facilities;700;1400 18;10;20000;Agricultural + Semi-natural areas + Wetlands;0;0.2 19;10;30000;Forests;0;0.2 20;10;40000;Wetlands;0;0 21;10;50000;Water bodies;0;0

4.2.2. List of Depth-Damage Curve: it is the list of groups of depth damage curves that are loaded into the database

File name	**ListDepthDamageCurves.csv**
The number of fields	2
Name of field	VulnID; Description
Data Type	Integer; Varchar (100)
Source	FloodRiskData
URL example file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Tables/ListDepthDamageCurves.csv
Description	List of Depth-Damage curve in the geodatabase: - VulnID : is the unique code as an integer number - Description: is the name of the group
Preview image	VulnID;Description 1;Hazus Model 2;Standard Method 3;Rhine Atlas Model 4;Flemish Model 5;Damage Scanner Model 6;Joint Research Centre/JRC Model 7;Multi-Colored Manual Model 8;FLEMO

4.2.3 Depth-Damage Curve: these are the tables containing the curves. As in the classic organization of the databases, the table is unique, and the different curves are identified by means of key fields: VulnID, DmgType and VulnType the meaning of which is described below.

File name	**DepthDamageCurves.csv**
The number of fields	6
Name of field	VulnID; OccuType; DmgType;VulnType; HydroValue;Damage
Data Type	Integer; Varchar (5); Integer; Integer; Real; Real
Source	FloodRiskData
URL example file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Tables/DepthDamageCurves.csv
Description	Depth-Damage curves fields: - VulnID : is the unique code of the group of curves - OccuType : is an alphanumeric code of the type of property or asset - DmgType : number of type damage: 1 for the structure and 2 for the content - VulnType: number of the type of vulnerability: 1 for water depth and 2 for water velocity (not used yet) - HydroValue: value of the hydraulic parameter (eg. water depth) - Damage: percentage of damage to the corresponding Hydro Value
Preview image	VulnID;OccuType;DmgType;VulnType;HydroValue;Damage;Original code 1;11100;1;1;-1.2192;0;RES3F 1;11100;1;1;-0.9144;0;RES3F 1;11100;1;1;-0.6096;0;RES3F 1;11100;1;1;-0.3048;0;RES3F 1;11100;1;1;0;0.05;RES3F 1;11100;1;1;0.3048;0.28;RES3F 1;11100;1;1;0.6096;0.29;RES3F 1;11100;1;1;0.9144;0.31;RES3F 1;11100;1;1;1.2192;0.36;RES3F 1;11100;1;1;1.524;0.37;RES3F 1;11100;1;1;1.8288;0.39;RES3F 1;11100;1;1;2.1336;0.4;RES3F ....

4.2.4 **Fatality Rate**: is the percentage of exposed population that could die.

File name	**FatalityRates.csv**
The number of fields	6
Name of field	Num; FRType; Fseverity; WarnTime; Understanding; FatRate
Data Type	Integer; Integer; Varchar (10); Rea; Varchar (10); Real
Source	FloodRiskData
URL example input file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Tables/FatalityRates.csv
Description	FatalityRates fields: - Num: number of the class of severity - FRType : number of type of the methodology referred - Fseverity : string of flood severity (low, medium or high) - WarnTime: warning time in hours - Understanding: degree to which the events that are about to unfold are understood by the people at risk - FatRate: percentage of exposed population could die
Preview image	FRType;num;Fseverity;WarnTime;Understanding;FatRate 0;3;HIGH;0;Vague;0.75 0;3;HIGH;24;Vague;0.75 0;2;MEDIUM;0;Vague;0.15 0;2;MEDIUM;0.25;Vague;0.15 0;2;MEDIUM;1;Vague;0.04 0;2;MEDIUM;24;Vague;0.03 0;1;LOW;0;Vague;0.01 0;1;LOW;0.25;Vague;0.01 0;1;LOW;1;Vague;0.007 0;1;LOW;24;Vague;0.0003 ......

4.2.5 Flood Severity:

File name	**FloodSeverity.csv**
The number of fields	4
Name of field	num; Fseverity; DV (m3/s); hrate (m/5min)
Data Type	Integer; Varchar (10); Double; Double
Source	FloodRiskData
URL example file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Tables/FloodSeverity.csv
Description	FatalityRates fields: - Num: number of the class of severity - Fseverity : string of flood severity (low, medium or high) - DV: parameter hydraulic that is the depth of water multiplied by velocity - hrate: speed of increase of the depth of water
Preview image	num;Fseverity;DV (m3/s);hrate (m/5min) 1;LOW;5;0 2;MEDIUM;15;0 3;HIGH;99999;3

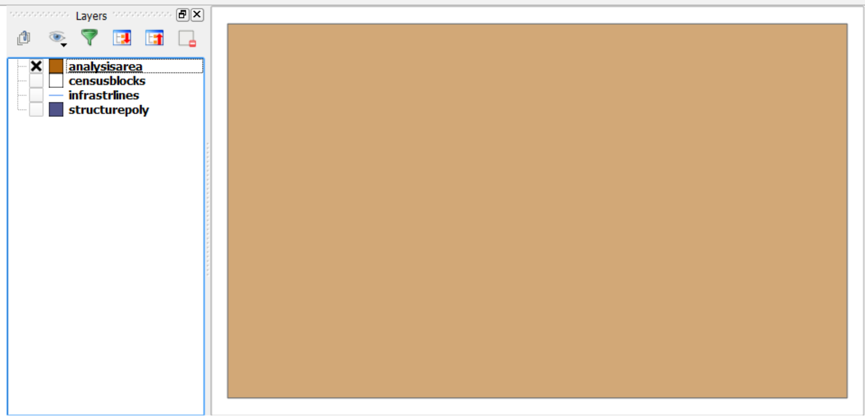
4.3 Exposure data

Exposure, refers to people, assets and activities, threatened or potentially threatened by a hazard. The *FloodRisk* plug-in stores exposure data of the study area in the geodatabase. The dataset consists of the following maps:

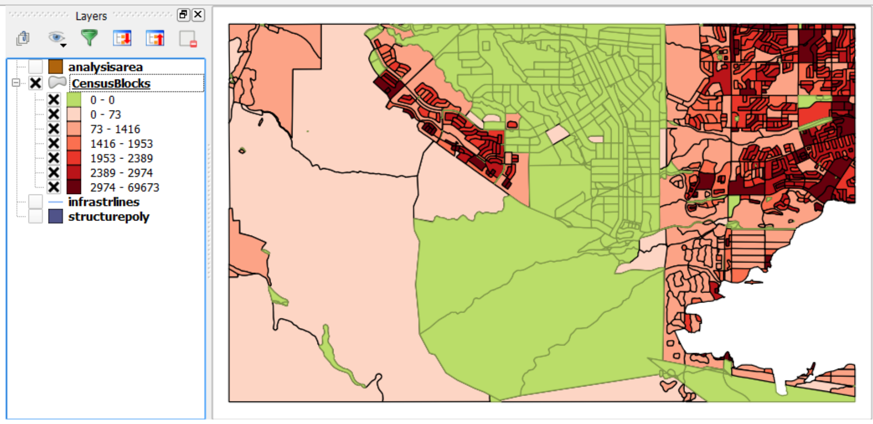
- the polygon boundary of the study area;
- census map of population;
- buildings and/or land use map;
- infrastructures lines maps (eg. roads, railways etc.) .

4.3.1 **Analysis Area**: the polygon boundary of the study area

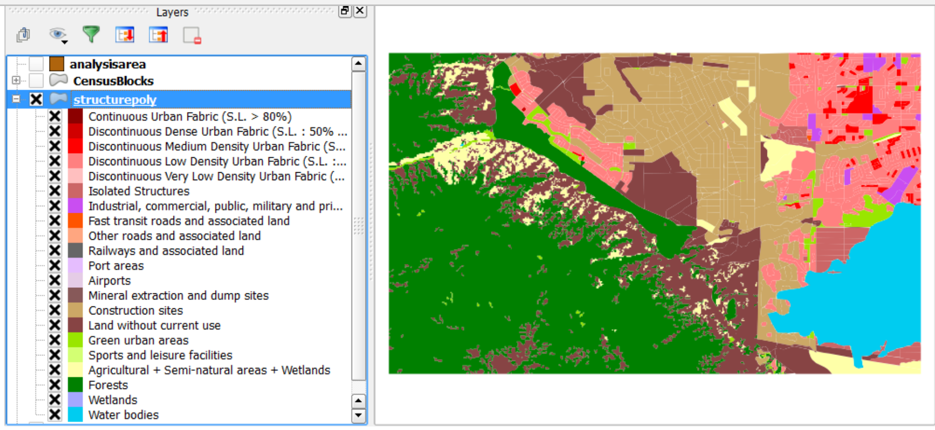
Table name	AnalysisArea
Geometry	Multipolygon
The number of fields	1
Name of field	Name
Data Type	Varchar (50)
Source	FloodRiskData
URL example input file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/AnalysisArea.shp
Description	The study area boundaries. This is the first map that must be loaded in

	the geodatabase. When subsequent maps are loaded, they are cut (clipped) along the outline of its border. Finally, if they are in a different reference system they are reprojected in the AnalysisArea reference system
Preview image	

4.3.2 **Census map**: polygons of census of population

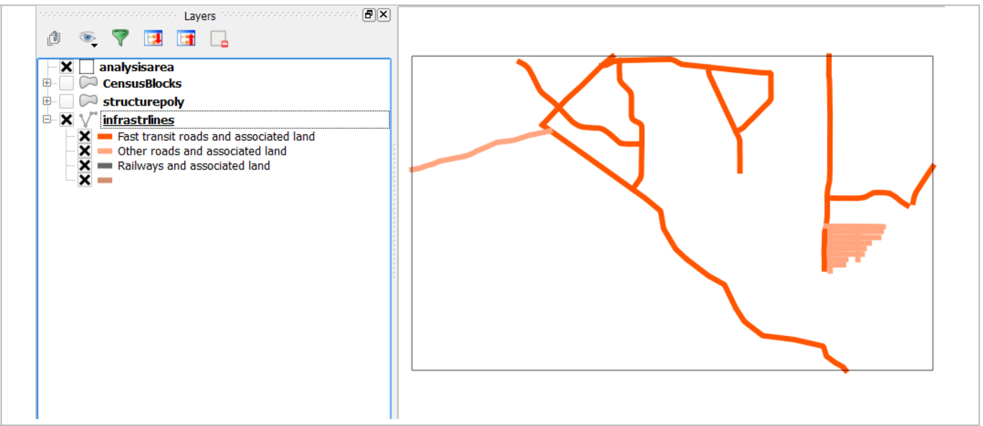
Table name	CensusBlocks
Geometry	Multipolygon
The number of fields	4
Name of field	CensID; Resident; Seasonal; Peop_kmq
Data Type	Real; Real; Real; Real
Source	FloodRiskData
URL example input file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/CensusBlocks.shp
Description	It is the map of population census data. CensusBlocks fields are: - CensID: is the unique code number of the polygon - Resident: number of people living in the polygon - Seasonal: number of people who come in seasonally - Peop_kmq: the total population density
Preview image	

4.3.3 **Buildings and/or land use map**: map of individual buildings or land use of the study area.

Table name	StructurePoly
Geometry	Multipolygon
The number of fields	3
Name of field	OccuType; Valstr;Valcon
Data Type	Varchar (5); Real; Real
Source	FloodRiskData
URL example input file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/PropertyPoly.shp
Description	It is the map of assets data. StructurePoly fields are: - OccuType: is an alphanumeric code of the type of property or asset - Valstr: unit value of the structure (Euro/m^2) - Valcon: unit value of the content (Euro/m^2)
Preview image	

4.3.4 **Infrastructures lines maps**: is the map of infrastructures lines eg. roads, railways etc.

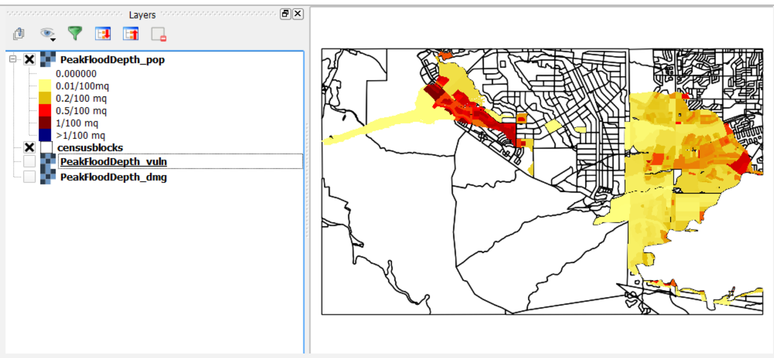
Table name	InfrastrLines
Geometry	Multipolygon
The number of fields	3
Name of field	OccuType; Valstr;Valcon
Data Type	Varchar (5); Real; Real
Source	FloodRiskData
URL example input file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/InfrasctrucLines.shp
Description	It is the map of assets data. InfrastrLines fields are: - OccuType: is an alphanumeric code of the type of property or asset - Valstr: unit value for each meter of structure (Euro/m) - Valcon: unit value for each meter of the content (Euro/m)

Preview image	

4.4 Output data

The outputs of the *FloodRisk* plug-in are grid maps of the spatial distribution of the population at risk, the potential loss of life and economic damage expected for the structures and for the content of the property at risk. Furthermore, two global summary tables of the results are provided.

4.4.1 **Population at risk layer**: maps of population at risk and number of potential fatalities

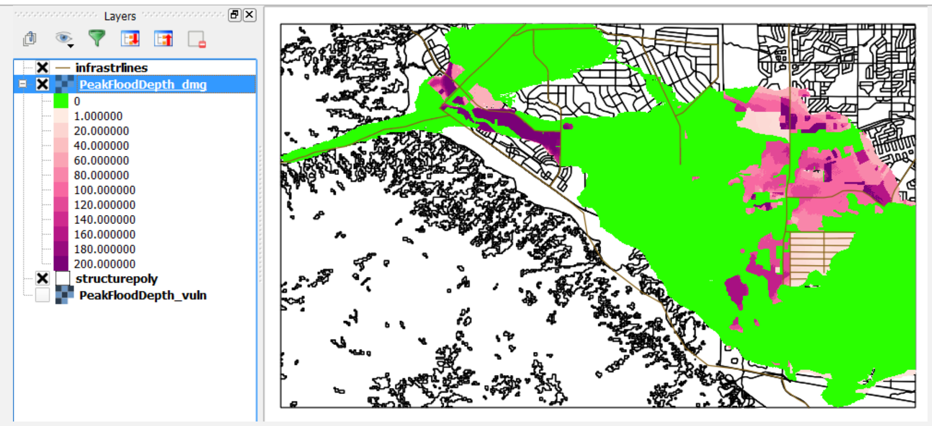
File name	**PeakFloodDepth_pop.tif**
Geometry	GeoTIFF
Dimensions	It has the same size as the input file PeakFloodDepth.tif (eg. X: 1593 Y: 961) Bands: 2
Data Type	Float32 - Thirty two bit floating point
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Output/PeakFloodDepth_pop.tif
Description	Maps of population at risk and number of potential fatalities. The maps are stored in the same GeoTIFF File Format having two output bands: - band1: population density at risk (people per sq. km of land area) - band2: loss of life density (people per sq. km of land area)
Preview image	

4.4.2 Global summary table of population at risk

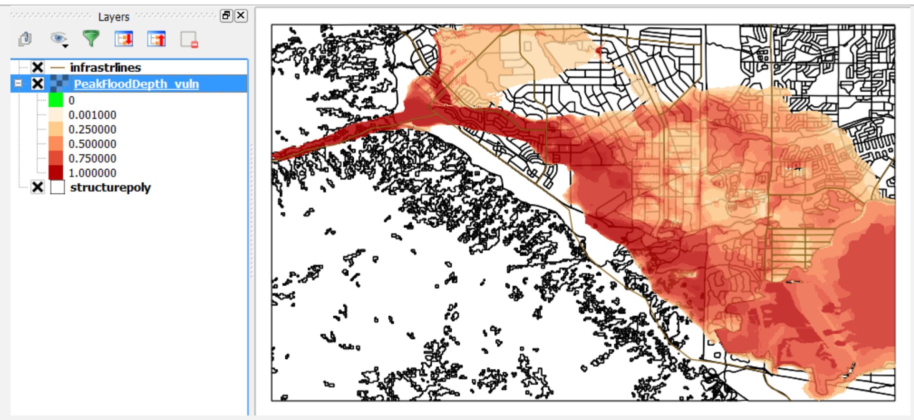
File name	**PeakFloodDepth_pop.csv**
The number of fields	6
Name of field	Range Water Depth (m);Flooded Area (m2);Resident Pop. at Risk;Seasonal Pop. at Risk;Total Population at Risk;Loss of Life
Data Type	Varchar (15); Integer; Integer; Integer; Integer; Integer
Source	FloodRiskData
URL example file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Output/PeakFloodDepth_pop.csv
Description	PeakFloodDepth_pop fields: - Range Water Depth (m): range for which refers - Flooded Area (m^2): flooded area in the range of water depth - Resident Pop. at Risk: number of people living in the range - Seasonal Pop. at Risk: number of seasonally people in the range - Total Population at Risk: total people at risk in the range - Loss of Life: number of potential loss of life in the range
Preview image	Range Water Depth (m);Flooded Area (m2);Resident Pop. at Risk;Seasonal Pop. at Risk;Total P 0.0-1.0;14791061;10245;3001;13246;6 1.0-2.0;17769334;12976;977;13953;7 2.0-3.0;10419689;2113;591;2704;11 3.0-4.0;4260025;499;446;945;86 >4;4251135;2905;5802;8707;5203 Total;51491244;28738;10817;39555;5313

4.4.3 Economic Damage Layer: map of damage to structures and their contents

File name	**PeakFloodDepth_dmg.tif**
Geometry	GeoTIFF
Dimensions	It has the same size as the input file PeakFloodDepth.tif (eg. X: 1593 Y: 961) Bands: 2
Data Type	Float32 - Thirty two bit floating point
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Output/PeakFloodDepth_dmg.tif
Description	map of damage to structures and their contents. The maps are stored in the same GeoTIFF File Format having two output bands: - band1: economic damage expected for the structures (Euro/m^2) - band2: economic damage expected for the contents (Euro/m^2)

Preview image	

4.4.4 **Vulnerability Layer**: map of percentage of damage to structures and their contents

File name	**PeakFloodDepth_vuln.tif**
Geometry	GeoTIFF
Dimensions	It has the same size as the input file PeakFloodDepth.tif (eg. X: 1593 Y: 961) Bands: 2
Data Type	Float32 - Thirty two bit floating point
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Output/PeakFloodDepth_vuln.tif
Description	map of damage to structures and their contents. The maps are stored in the same GeoTIFF File Format having two output bands: - band1: percentage economic damage expected for the structures - band2: percentage economic damage expected for the contents
Preview image	

4.4.5 Global summary table of damage

File name	**PeakFloodDepth_dmg.csv**
The number of fields	6
Name of field	Code;Description;Valstr_Euro;ValCon_Euro;DamageStr_Euro;DamageCon_Euro
Data Type	Varchar (5); Varchar (150); Integer; Integer; Integer; Integer
Source	FloodRiskData
URL example file	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/Output/PeakFloodDepth_dmg.csv
Description	PeakFloodDepth_pop fields: - Code: alphanumeric code of the type of property or asset - Description: description of the property - Valstr_Euro: value in euro for structures of the type of Code - ValCon_Euro: value in euro for contents of the type of Code - DamageStr_Euro: damage in euro for structures of the type of Code - DamageCon_Euro: damage in euro for structures of the type of Code
Preview image	Code;Description;Valstr_Euro;ValCon_Euro;DamageStr_Euro;DamageCon_Euro 11100;Continuous Urban Fabric (S.L. > 80%);0;0;0;0 11210;Discontinuous Dense Urban Fabric (S.L. : 50% - 80%);7879600;3939800;2808600;1874200 11220;Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%);203191000;101595500;65918700;40930000 11230;Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%);1614429100;807214600;653092600;440572100 11240;Discontinuous Very Low Density Urban Fabric (S.L. < 10%);0;0;0;0 11300;Isolated Structures;48236300;72354500;14859800;28146700 12100;Industrial, commercial, public, military and private units;342799000;1199796600;59665400;556797500 12210;Fast transit roads and associated land;95509900;3820500;0;0 12220;Other roads and associated land;22413400;896600;0;0 12230;Railways and associated land;0;0;0;0 12300;Port areas;0;0;0;0 12400;Airports;0;0;0;0 13100;Mineral extraction and dump sites;0;0;0;0 13300;Construction sites;0;15069000;0;8439700 13400;Land without current use;0;0;0;0 14100;Green urban areas;0;325500;0;216400 14200;Sports and leisure facilities;0;0;0;0 20000;Agricultural + Semi-natural areas + Wetlands;0;420000;0;274500 30000;Forests;0;284600;0;208400 40000;Wetlands;0;0;0;0 50000;Water bodies;0;0;0;0

5 Activate the *FloodRisk* plugin

FloodRisk is one of the plugins which are available in the QGIS Official Repository and its source code is available on *GitHub* (check https://github.com/FloodRiskGroup/floodrisk). The *FloodRisk* plugin is developed and tested on the long term release QGIS 2.8, therefore, we not guarantee the compatibility with more recent QGIS releases. However, we kindly invite you to report any issue on the QGIS Bug Tracking System (http://hub.qgis.org/wiki/quantum-gis/Bugreports) or ask for support at FloodRiskGroup@rse-web.it.

First this plugin needs to be installed and activated using the QGIS Plugin Manager (see http://docs.qgis.org/2.8/en/docs/user_manual/plugins/plugins.html#managing-plugins): please click on *Plugins menu >Manage and Install Plugins*. In the *Plugin Manager* dialog, you will see a list of several external plugins. Therefore, let’s type "FloodRisk" in the *Search box* and, then, select it and click on *install plugin* (Fig.2.).

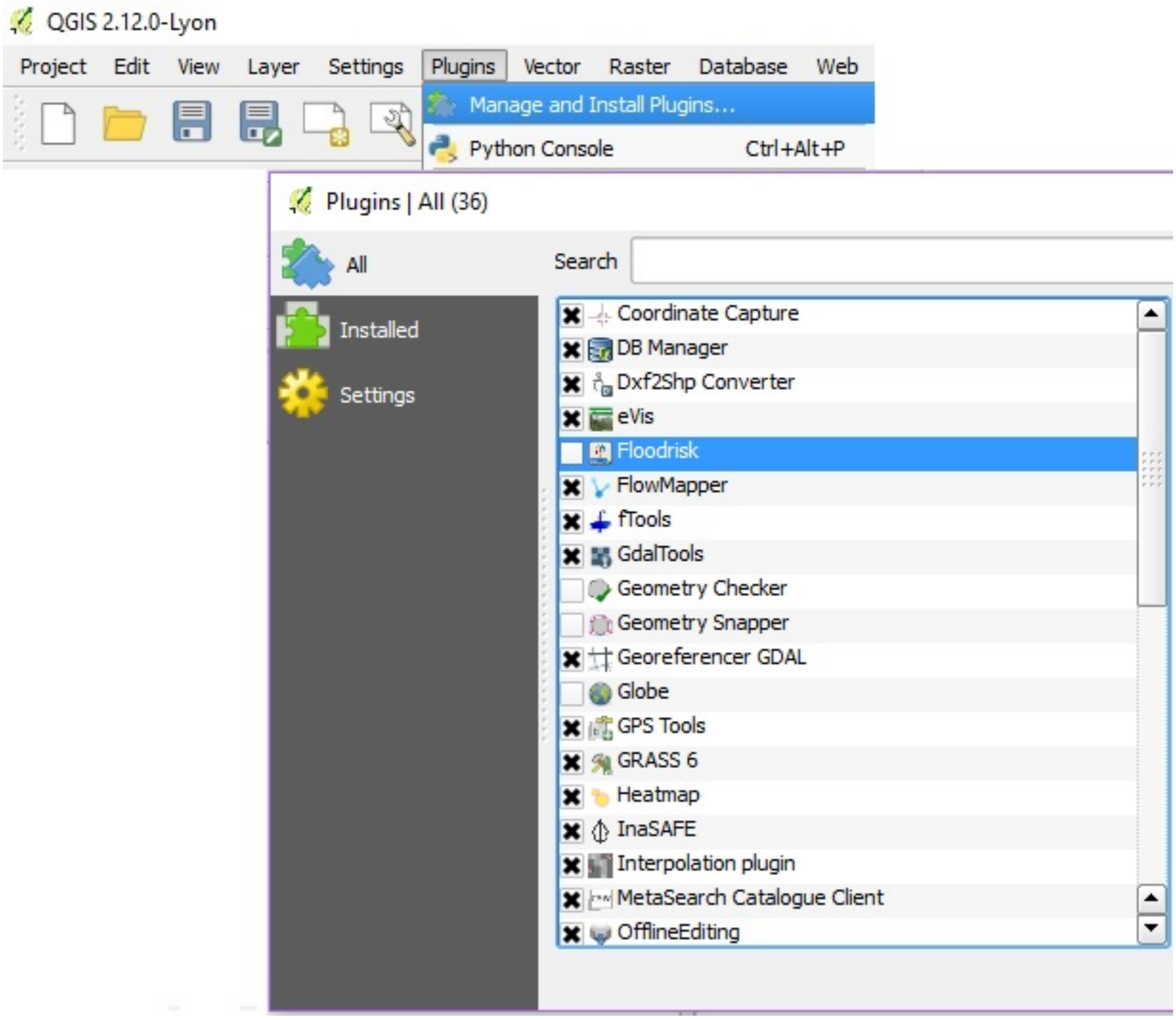


Figure 2 - QGIS Plugin Manager

After successfully installing *FloodRisk*, you should now have the *FloodRisk* **icon** in the Plugin menu and the **toolbar** menu (Fig. 3). To retrieve the *FloodRisk* toolbar, you can right-click on the QGIS top toolbar and check for *FloodRisk*:

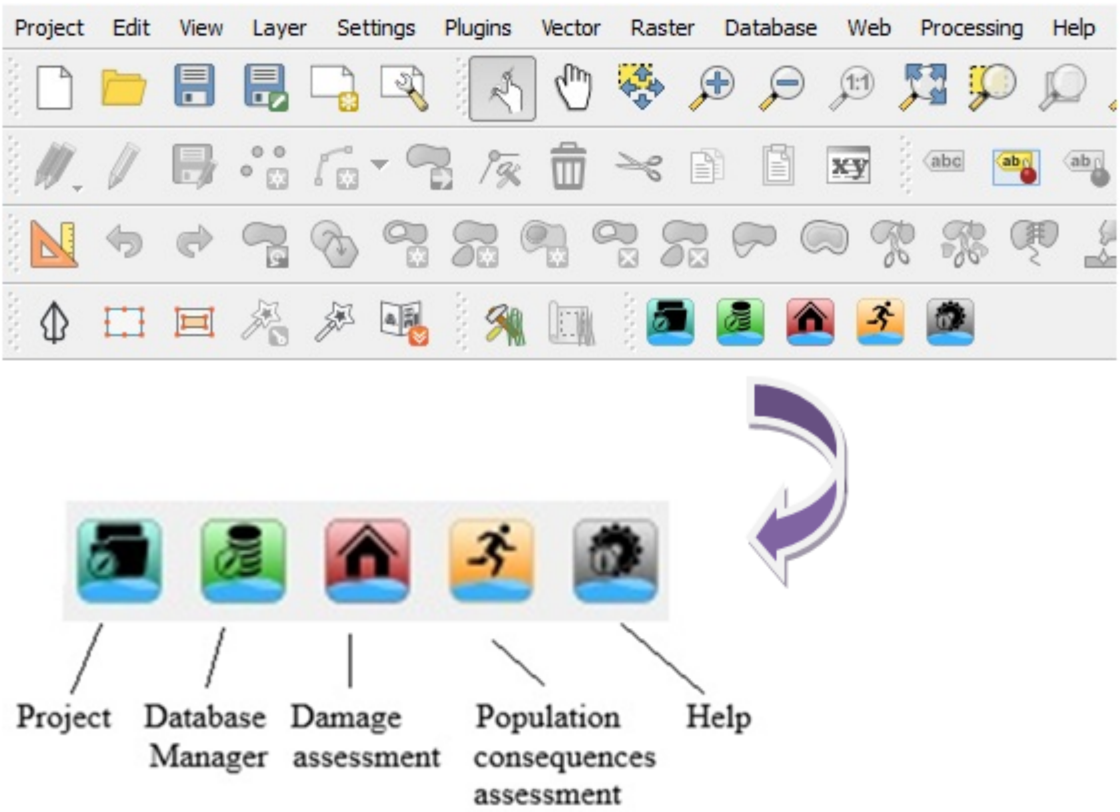


Figure 3 - FloodRisk toolbar

6 *FloodRisk* Application Help: Understanding Interface

The *FloodRisk* plugin is very simple to handle and provides an intuitive graphical user interface [2]:

1. The **Project Management** window (Fig. 4) allows you to manage a *FloodRisk* project: the latter serves as a container for all the different parts that together give a complete representation of each scenario's dataset. Below you can see an example of a project window with the list of all the input files.
The user must choose the name of the **project file (* .dmg)**. The latter is an eXtensible Markup Language (XML) file in which are stored the PATH_NAME of the input file, e.g. flood hazard characteristics data, receptors and vulnerability dataset.

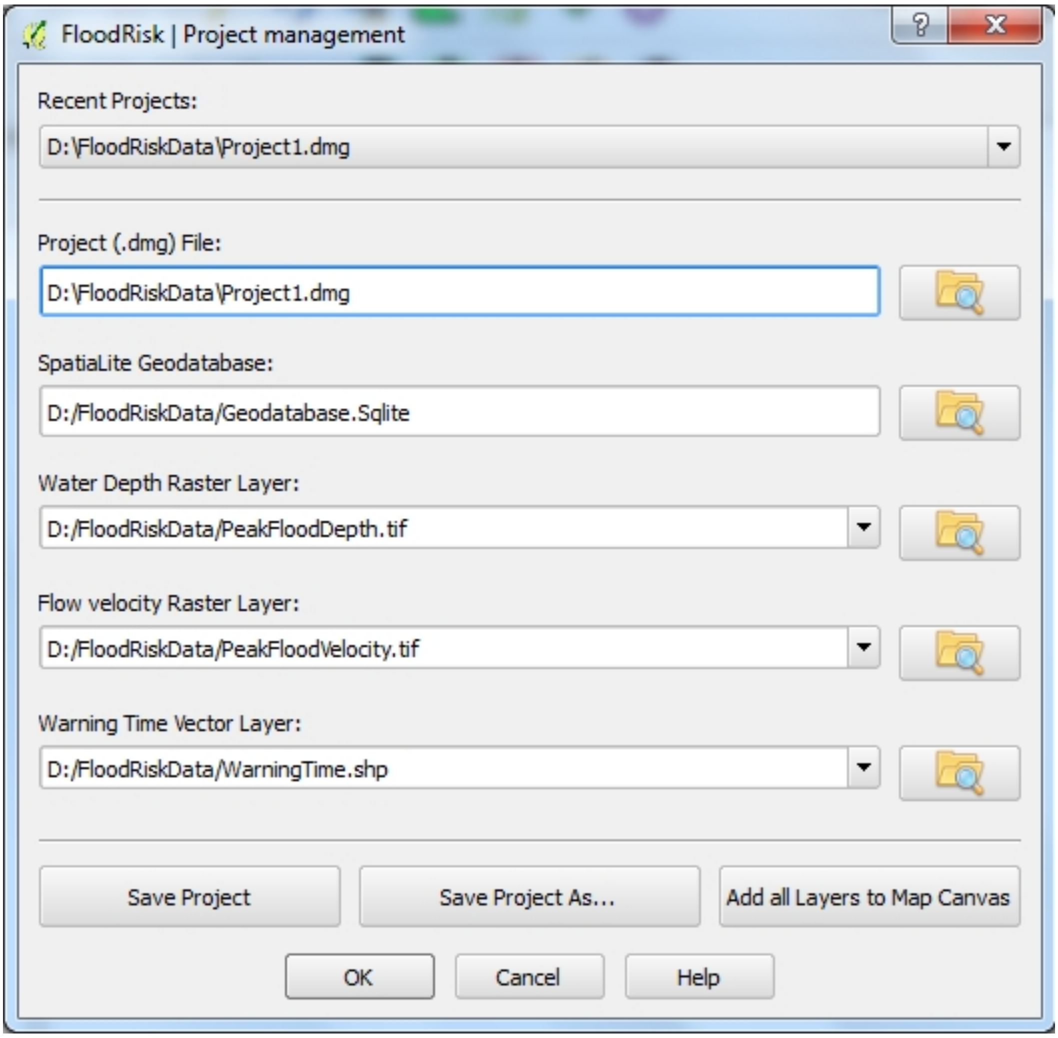


Figure 4 - Project Management window

Note: *we refer for type and description of input data to section* ***Dataset****.*

2. The **Database Manager** window (Fig. 5) allows you to create or modified a *SpatiaLite* geodatabase having the expected data model and upload all the data into it. Data stored in the geodatabase concern **population** and **assets at risk** and their **vulnerability** in respect of floods.

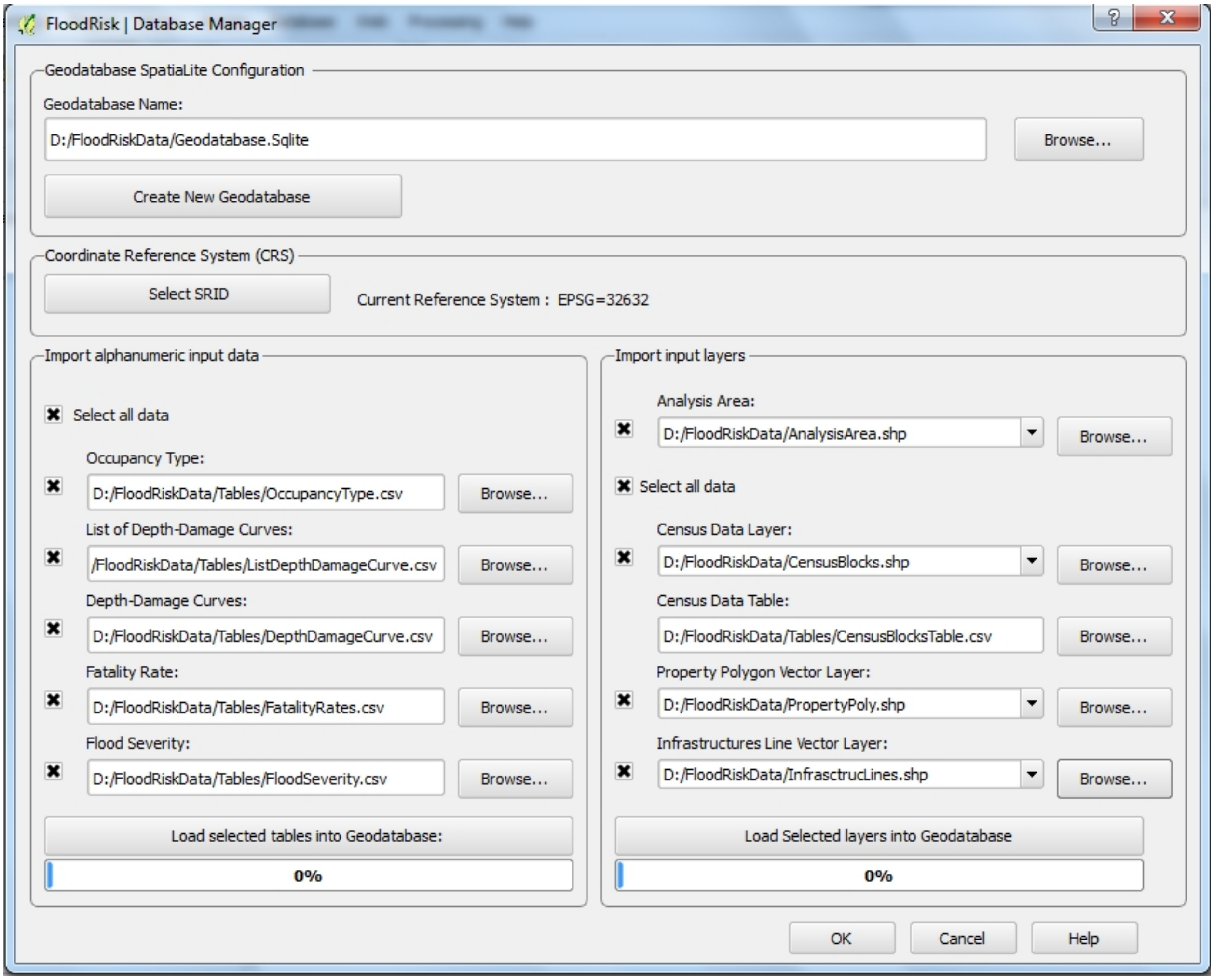


Figure 5 - Database Manager Window

- The upper side of the window allows you to create a *new SpatiaLite geodatabase*. After the creation of the geodatabase and before loading geographic data, it is necessary to define its *geographic coordinate reference system (CRS).*

Note: *You can change* ***CRS*** *until the "AnalysisArea" layer is loaded, after this option is disabled. Moreover, the geodatabase must be emptied of all geographic data (i.e. AnalysisArea, CensusBlocks, StructurePoly and InfrastrLines) to enable this option again.*

- The left side of the window allows you to upload or update the *vulnerability dataset,* such as *curves, occupancy type* for *land use of buildings maps* and *categories of flood fatality rate* and *Flood Severity degree*. These are alphanumeric data and could be loaded from ***.csv files**.
- The right part of the window allows you to upload or update the **exposure geographic data**. These are *vector data type* and should be loaded as a **shapefiles (*.shp)**. The system does could work at different scale on the basis of the purpose of the study: it means that exposure data input could be in the form of a **land use map** or **urban buildings maps**: these

input data spatial detail affects the final results. In the following the list of input **exposure** *shapefile*:

1. **AnalysisArea**: polygon *shapefile*
2. **Census Data Layer**: polygon *shapefile* having fields **CensID** type *Real*; **Resident** type *Integer*; **Seasonal** as *Integer*
3. **Census Data Table**: *csv* file having fields **CensID** and **Resident**
4. **Property Polygon Vector Layer**: polygon *shapefile* having fields **OccuType** type *VARCHAR(5)*; **Valstr** type *Real*; **Valcon** as *Real*
5. **Infrastructures Line Vector Layer**: line *shapefile* having fields **OccuType** type *VARCHAR(5)*; **Valstr** type *Real*; **Valcon** as *Real*

3. The **Direct Economic Damage** window (Fig. 6) allows the assessment of the flood direct economic damage for structures and content of properties at risk using the so called vulnerability depth-damage functions.

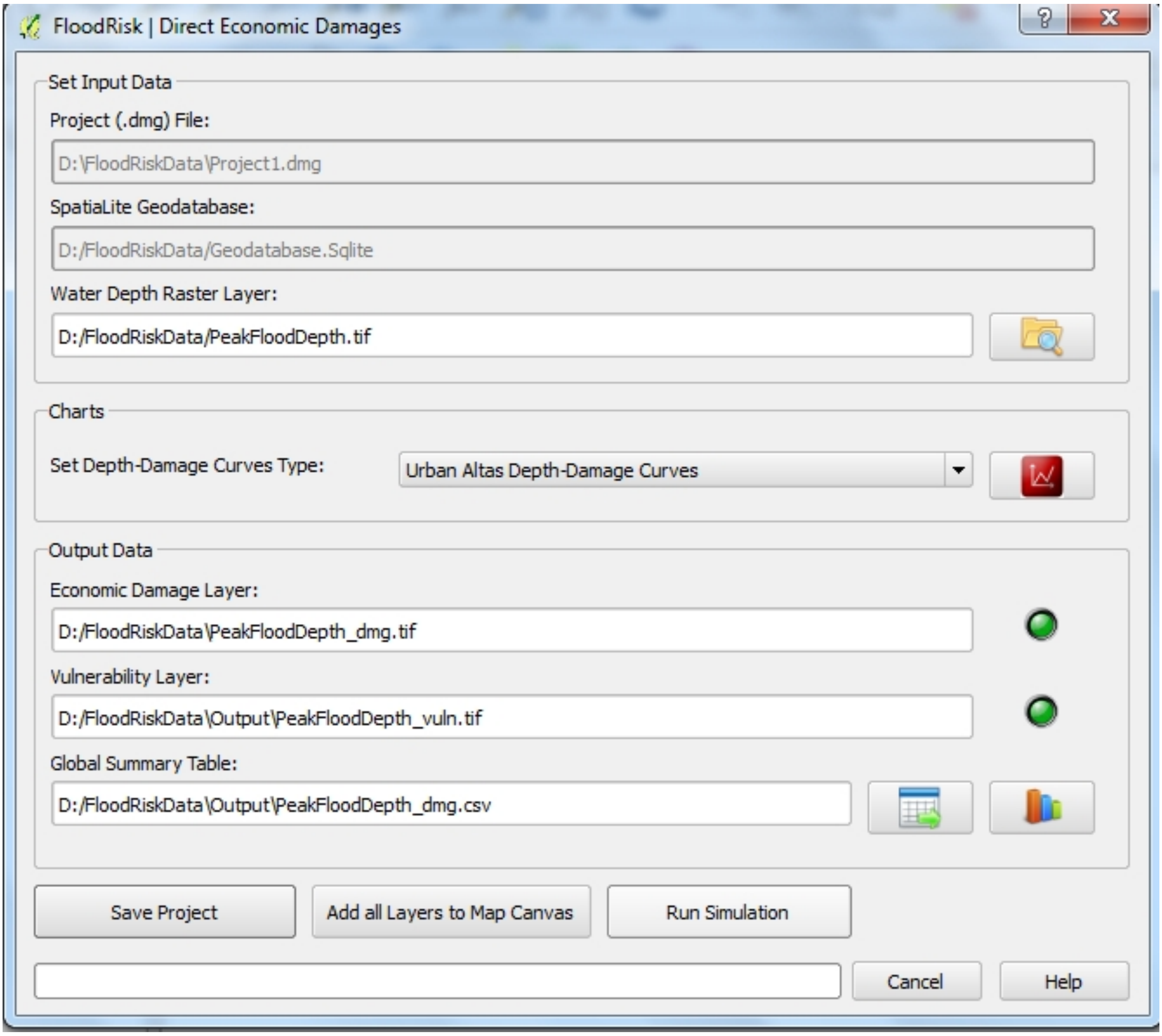


Figure 6 - Direct Economic Damages window

- The Input data are automatically visualized in the **Set Input Data box,** if you have created a project file.
- The different types of depth-damage curves could be visualized by the **Charts Box** in the **Charts window**.
- The results are maps of **damage** and **vulnerability** to residential, commercial and industrial properties and a **global summary table** of the results which are also displayed in form of histogram.

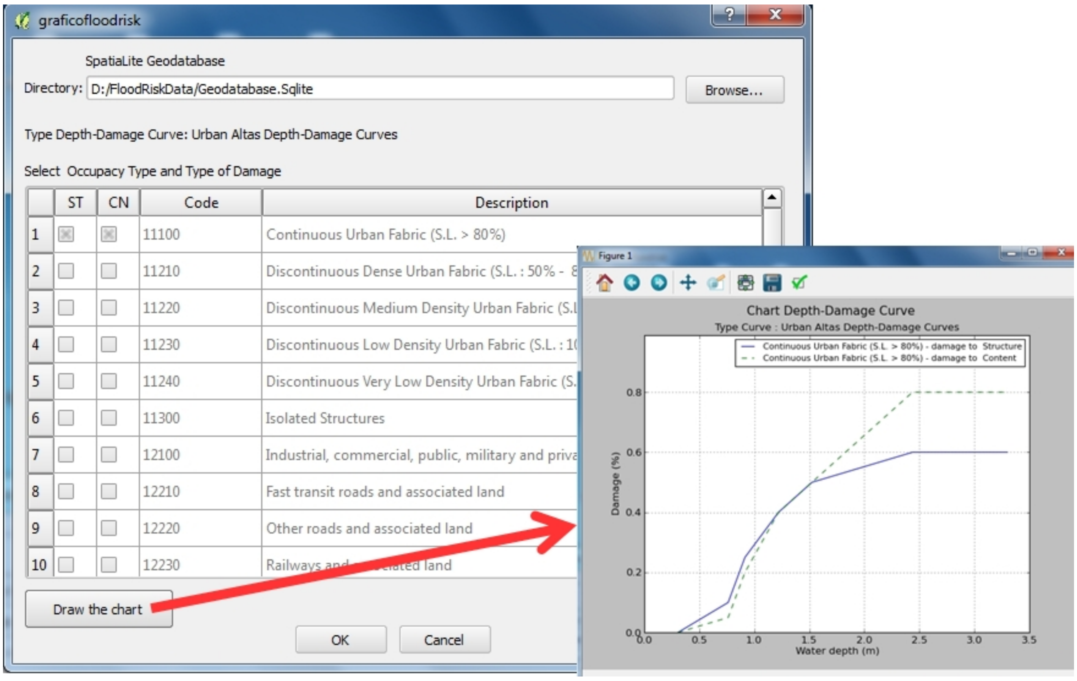


Figure 7 - Charts window and visualization of some example depth-damage curves

4. The **Loss of Life Assessment** window (Fig. 8) allows you to assess the map of the **population at risk** and the **number of potential fatalities**. The map of the *population at risk* is obtained by superimposing the *inundation map* and the *population density map*. Having calculated the map of the *population at risk*, the number of potential fatalities is obtained by multiplying *population at risk* and the *fatality rate* estimated with several methods available in literature ([7], [8]).

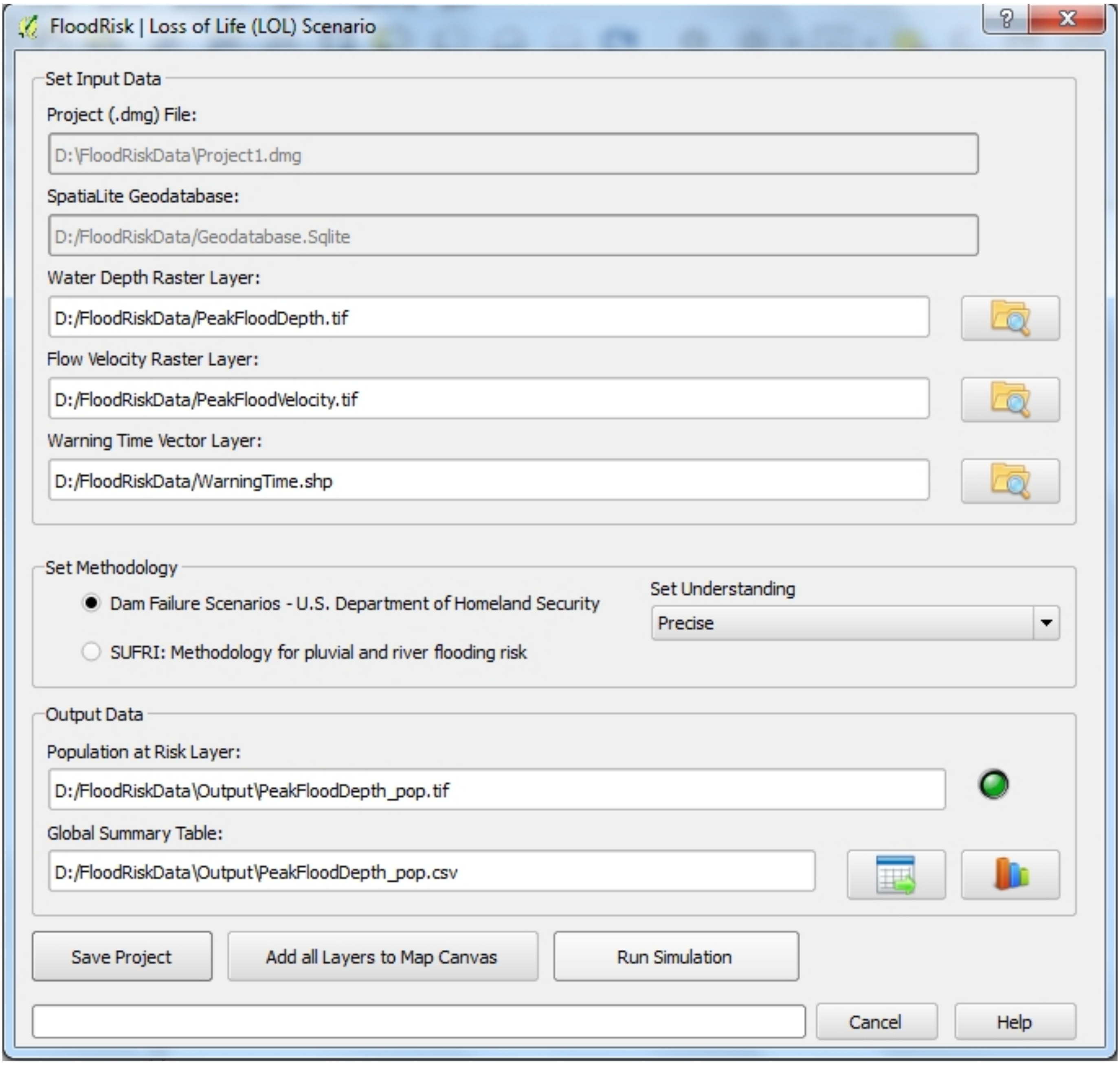


Figure 8 - Loss of life assessment window

- The Input data are directly showed in the **Set Input Data box,** if you have created a project file.
- The **Set Methodology box** presents two available methods for the assessment of potential loss of life. DHS [8] concerns the potential risks associated with the failure or disruption of dams, SUFRI [7] for river and dam-break flooding. For both methodologies, the *fatality rates* depend on *warning time*, *flood severity* and on the *effectiveness in the evacuation of the population*. The last factor is evaluated differently by the two methodologies.

In **DHS** methodology [8] this factor is defined as "Flood Severity Understanding" and describe the degree to which the events that are about to unfold are understood. The flood severity understanding categories are as follows:

- **Vague** Understanding of Flood Severity: warning issuers have not yet seen the dam fail or do not comprehend the true magnitude of the flood that is about to ensue. For simplicity we can consider this situation when the event occurs at night.
- **Precise** Understanding of Flood Severity: warning issuers have an excellent understanding of the flooding due to observations of the flooding. For simplicity we can consider this situation when the event occurs by day.

In **SUFRI** methodology, [7], methodology the third factor is considered as a degree of readiness of population. Ten categories (C1 to C10) are established, depending on the existence of non-structural measures: public education on flood risk, warning and communication system, and, coordination between emergency agencies and authorities (see Tab. 1).

Table 1. Fatality rates in case of river or dam-break flooding ([3], [7]).

ID	Category for the case study	Warning Time (h)	Flood Severity		
			High	Medium	Low
C1	– There is no public education on flood risk terms. – No warning systems, no EAP (Emergency Action Plan). – There is no coordination between emergency agencies and authorities. – No communication mechanisms to the public.	0 0.25 0.625 1 1.5 24	0.9 0.9 0.7 0.3 0.3 0.08	0.3 0.3 0.08 0.06 0.0002 0.0002	0.02 0.02 0.015 0.0006 0.0002 0.0001
C2	– There is no public education on flood risk terms. – There is no EAP, but there are other warning systems. – There is no coordination between emergency agencies and authorities. – No communication mechanisms to the public.	0 0.25 0.625 1 1.5 24	0.9 0.9 0.675 0.3 0.3 0.075	0.3 0.3 0.075 0.055 0.0002 0.0002	0.02 0.02 0.014 0.00055 0.0002 0.0001
C3	– There is no public education on flood risk terms. – There is EAP, but it has not been applied yet. – Some coordination between emergency agencies and authorities (but protocols are not established). – No communication mechanisms to the public.	0 0.25 0.625 1 1.5 24	0.9 0.85 0.6 0.3 0.3 0.075	0.3 0.2 0.07 0.05 0.0002 0.0002	0.02 0.015 0.012 0.0005 0.0002 0.0001
C4	– There is no public education on flood risk terms. – EAP is already applied. – Coordination between emergency agencies and authorities (there are protocols). – No communication mechanisms to the public.	0 0.25 0.625 1 1.5 24	0.9 0.75 0.5 0.3 0.15 0.04	0.3 0.15 0.04 0.03 0.0002 0.0002	0.02 0.01 0.007 0.0003 0.0002 0.0001

C5	– There is no public education on flood risk terms. – EAP is already applied. – Coordination between emergency agencies and authorities (there are protocols). – Communication mechanisms to the public (not checked yet).	0 0.25 0.625 1 1.5 24	0.9 0.75 0.5 0.3 0.15 0.375	0.3 0.15 0.0375 0.0275 0.0002 0.0002	0.02 0.01 0.0065 0.000275 0.0002 0.0001
C6	– There is no public education on flood risk terms. – EAP is already applied. – Coordination between emergency agencies and authorities (there are protocols). – Communication mechanisms to the public.	0 0.25 0.625 1 1.5 24	0.9 0.75 0.475 0.3 0.15 0.035	0.3 0.15 0.035 0.025 0.0002 0.0002	0.02 0.01 0.006 0.00025 0.0002 0.0001
C7	– Public education. – EAP is already applied. – Coordination between emergency agencies and authorities (there are protocols). – Communication mechanisms to the public.	0 0.25 0.625 1 1.5 24	0.9 0.65 0.4 0.3 0.1 0.02	0.3 0.1 0.02 0.01 0.0002 0.0002	0.02 0.0075 0.002 0.0002 0.0002 0.0001

- Results are maps of **population at risk** and **number of potential fatalities** and a **global summary table** of the results which are also displayed in form of an histogram.

Note: *we refer to section* ***Dataset*** *for a detailed description of input data.*

7 Basic Tutorial: Estimate potential direct losses due a dam-break event

7.1 Introduction

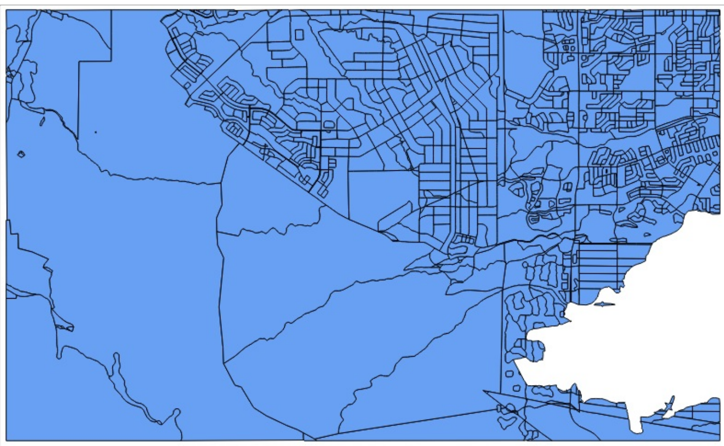
The purpose of this basic exercise is to present the use of the *FloodRisk* plugin for the quantitative estimation of the consequences, in terms of economic damage and loss of life, due a dam failure near a populated area with complex socio-economics context.

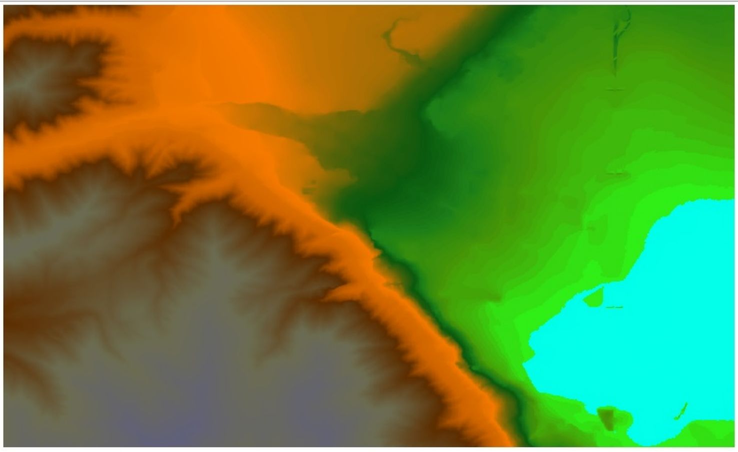
7.2 Data for exercise

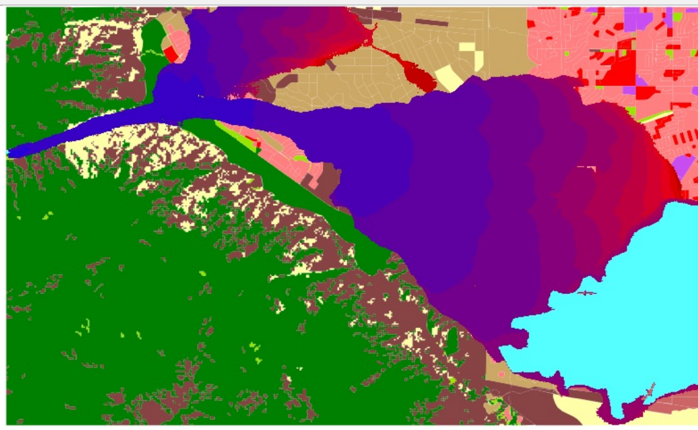
Firstly, you must download the *example dataset* available on *Github* (https://github.com/FloodRiskGroup/floodrisk-doc). The dataset was originally provided by [9] for the workshop on the benchmarking of risk analysis for dam breaks entitled "Computational

Challenges in Consequence Estimation for Risk Assessment” and successively modified by authors for this tutorial.

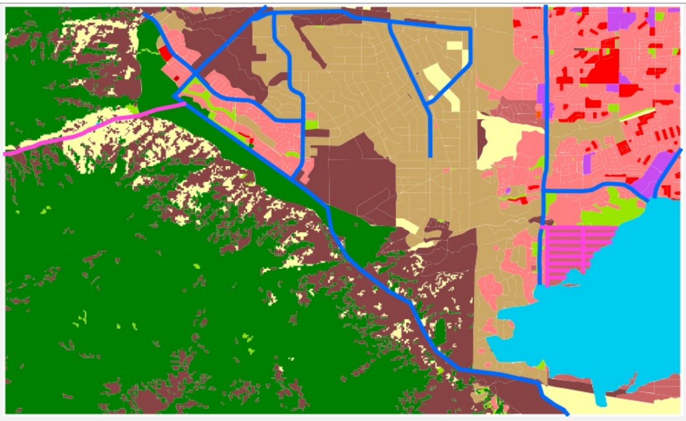
File name	AnalysisArea.shp
Geometry	Polygon
The number of features	1
Attribute field	Shape_Area
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/AnalysisArea.shp
Description	The study area boundaries
Preview image	

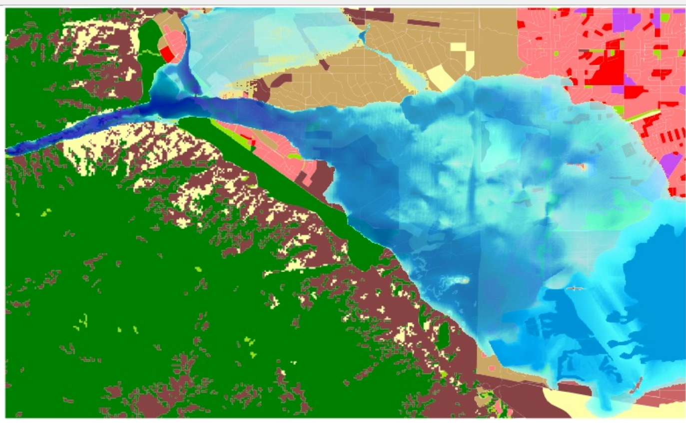
File name	CensusBlocks.shp
Geometry	Polygon
The number of features	1021
Attribute fields	CensID; Resident; Seasonal
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/CensusBlocks.shp
Description	The distribution and density of the population within the study area
Preview image	

File name	DEM.tif
Geometry	Raster
Unit	meters
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/DEM.tif
Description	The Digital Elevation Model of the study area
Preview image	

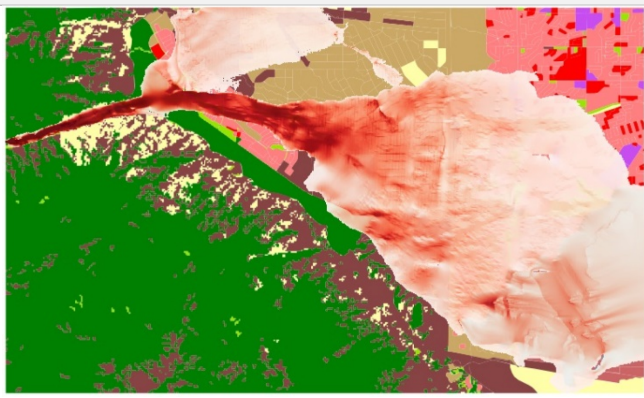
File name	FloodWaveArrivalTime.tif
Geometry	Raster
Unit	minutes
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/FloodWaveArrivalTime.tif
Description	This file contains information about the amount of time between the reception of a warning and the instant in which the population of each structure could be affected by the flood event
Preview image	

File name	InfrastrucLines.shp

Geometry	Line
The number of features	20
Attribute fields	OccuType; Valstr; Valcon
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/InfrasctrucLines.shp
Description	This file is containing the classification of the infrastructures lines within study area and the value of structure and content for each class
Preview image	

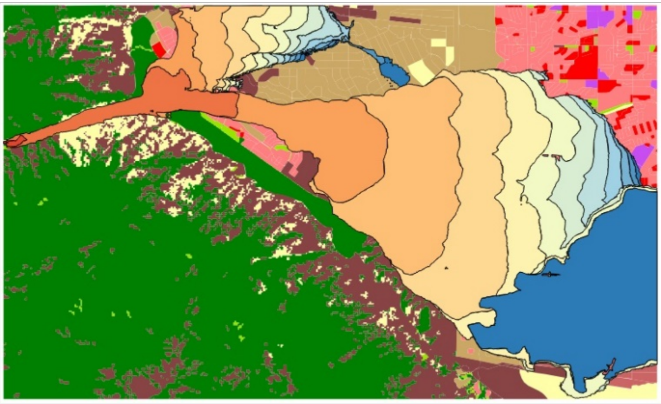
File name	PeakFloodDepth.tif
Geometry	Raster
Unit	meters
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/PeakFloodDepth.tif
Description	This file is the result of a 2D model and describe the characteristics of water depth in any cell of the raster affected by flood in the study area
Preview image	

File name	PeakFloodVelocity.tif

Geometry	Raster
Unit	Meters per second
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/PeakFloodVelocity.tif
Description	This file is the result of a 2D model and describe the characteristics of watervelocity in any cell of the raster affected by flood in the study area
Preview image	

File name	PropertyPoly.shp
Geometry	Polygon
The number of features	2997
Attribute fields	OccuType; Valstr; Valcon
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/PropertyPoly.shp
Description	This file is containing a land use classification (Urban Atlas classes) and for each class information (the value of structure and content) about the assets within that class.
Preview image	

File name	WarningTime.shp
Geometry	Polygon

The number of features	513
Attribute field	TimeHours
Source	FloodRiskData
URL	https://github.com/FloodRiskGroup/FloodRisk-doc/blob/master/FloodRiskData/WarningTime.shp
Description	This file contains information about the amount of time between the reception of a warning and the instant in which the population of each structure could be affected by the flood event
Preview image	

***Note**: the authors have done a reclassification of the original categories in the of land use data used in this exercise following the scheme of the Urban Atlas of the European Environmental Agency, which is available for the major cities of Europe; we have chosen the Urban Atlas land use classification, in this example, because it provides pan-European comparable land use and land cover data for Large Urban Zones with more than 100,000 inhabitants as defined by the Urban Audit.*

Table 2 – Urban Atlas classification

code	Description
11100	Continuous Urban Fabric (S.L. > 80%)
11210	Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)
11220	Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%)
11230	Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)
11240	Discontinuous Very Low Density Urban Fabric (S.L. < 10%)
11300	Isolated Structures
12100	Industrial, commercial, public, military and private units
12210	Fast transit roads and associated land
12220	Other roads and associated land
12230	Railways and associated land
12300	Port areas
12400	Airports
13100	Mineral extraction and dump sites
13300	Construction sites

13400	Land without current use
14100	Green urban areas
14200	Sports and leisure facilities
20000	Agricultural + Semi-natural areas + Wetlands
30000	Forests
40000	Wetlands
50000	Water bodies

7.3 Exercise

Firstly, click on  **Project management icon** of the *FloodRisk* toolbar in order to open **Project management window** (Fig. 4). The form of Fig. 9 allows you to upload all the input data required to run the *FloodRisk* Plugin and organize them in a project file *(*.dmg).*

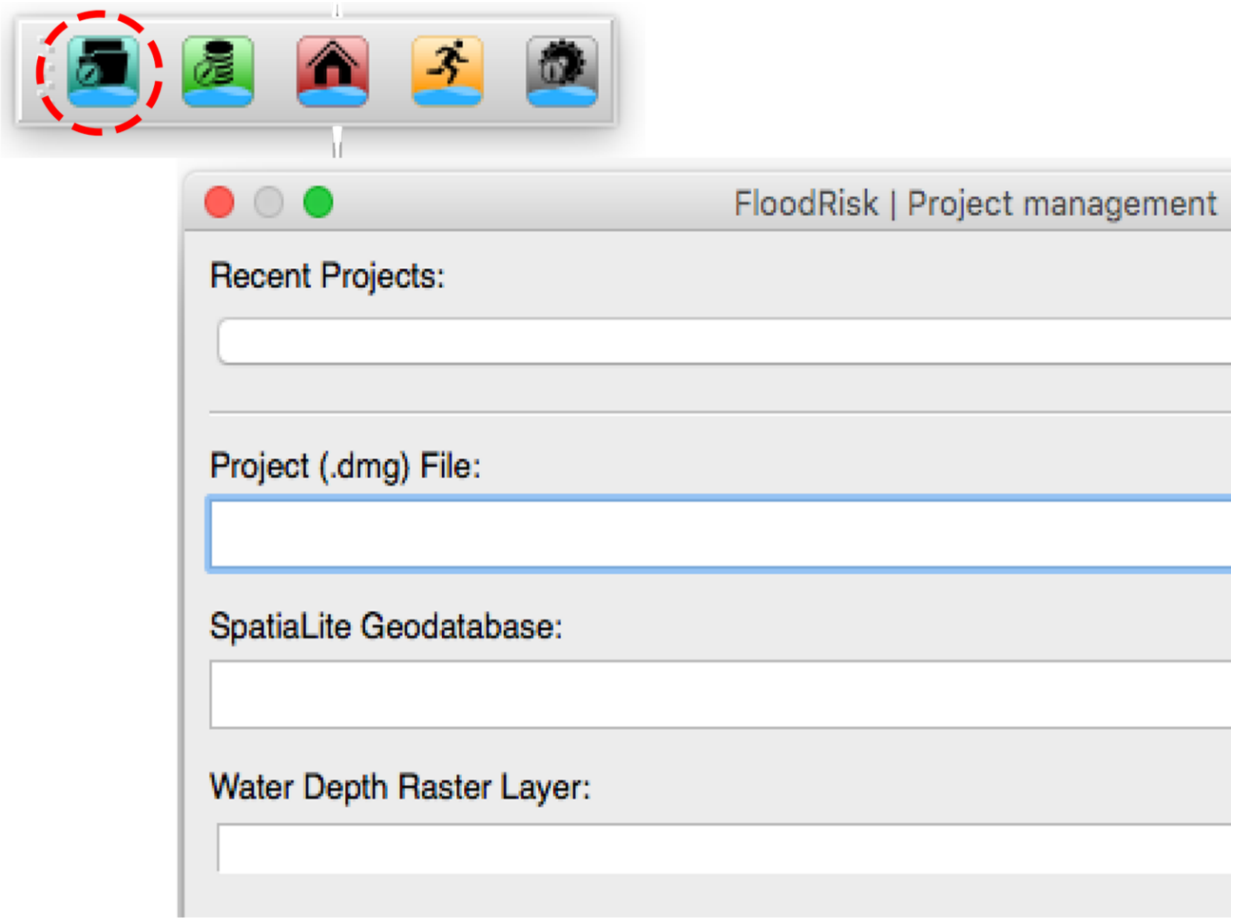


Figure 9 - Project Management Frame opening by toolbar

Now, choose a path and name for the project in the “Project File” wizard, for example “DamBreak_datatest” (Fig.10).

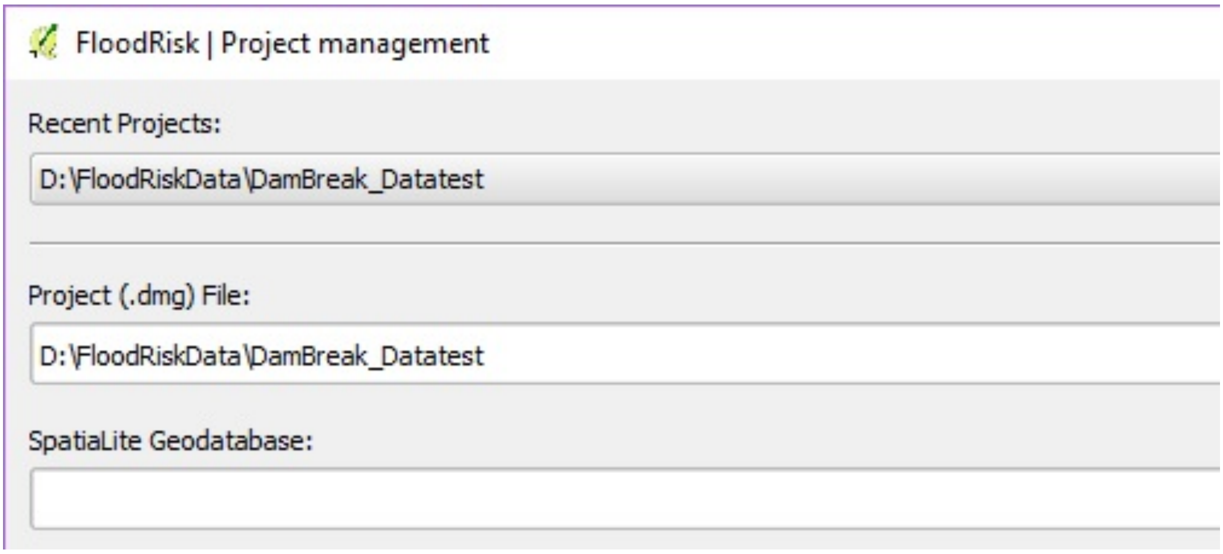


Figure 10 - Project path and name

Then, you can upload the geodatabase, named “Geodatabase.Sqlite”, through the browse button  of the *SpatialLite Geodatabase Wizard*, (Fig.11).

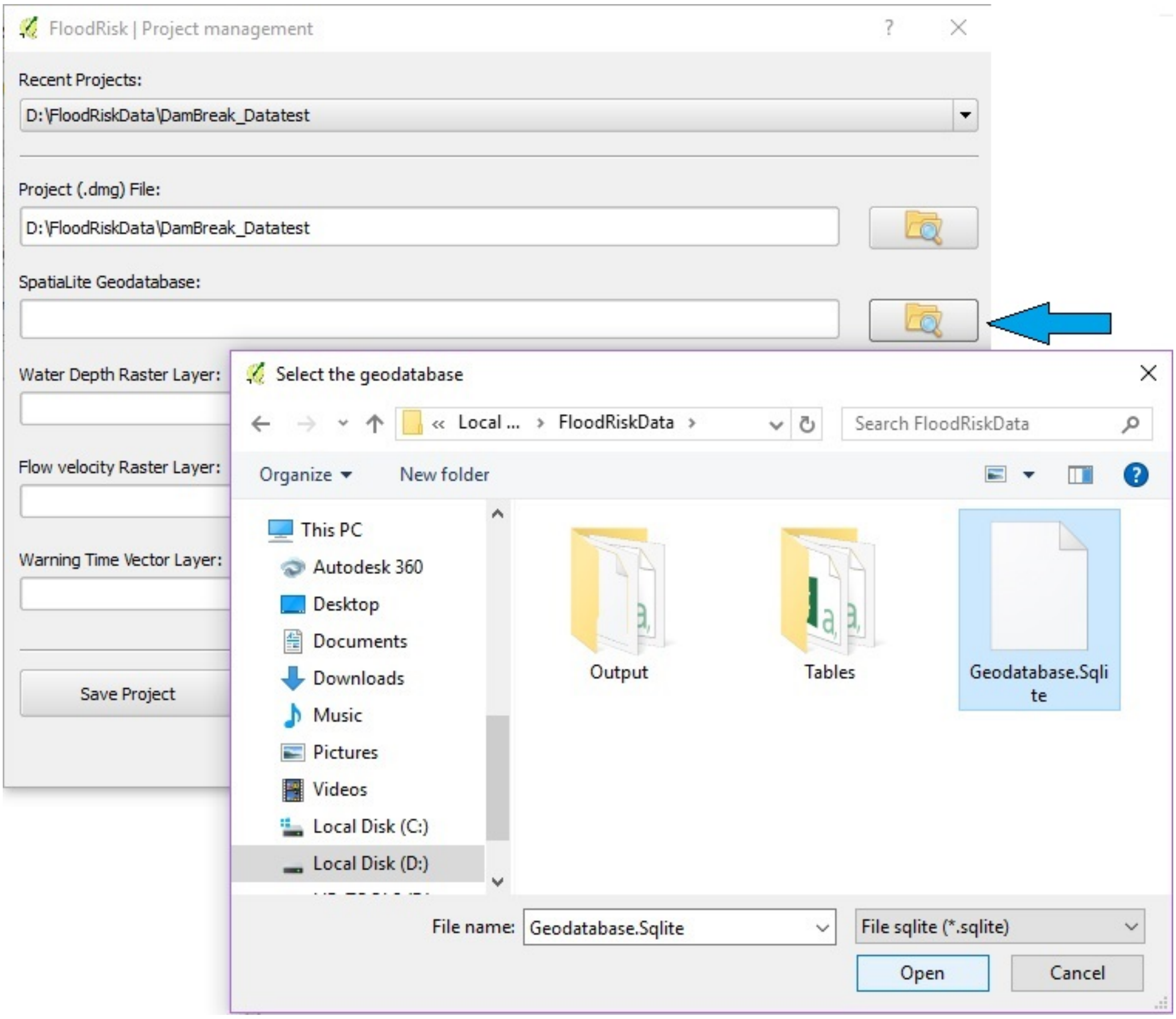


Figure 11 - Geodatabase upload

Next, you can upload the other hazard input files: "PeakFloodDepth.tif" in the *Water Depth Raster Layer Combobox*, "PeakFloodVelocity.tif" in the *Flow Velocity Raster Layer Combobox* and "WarningTime.shp" in the *Warning Time Vector Layer* (Fig.12).

***Note**: You can upload these data by browsing for the data path or, if you have just uploaded them in the QGIS TOC (Table Of Contents), you can directly choose, through the down arrow of the combobox, the name of the file that you want to upload.*

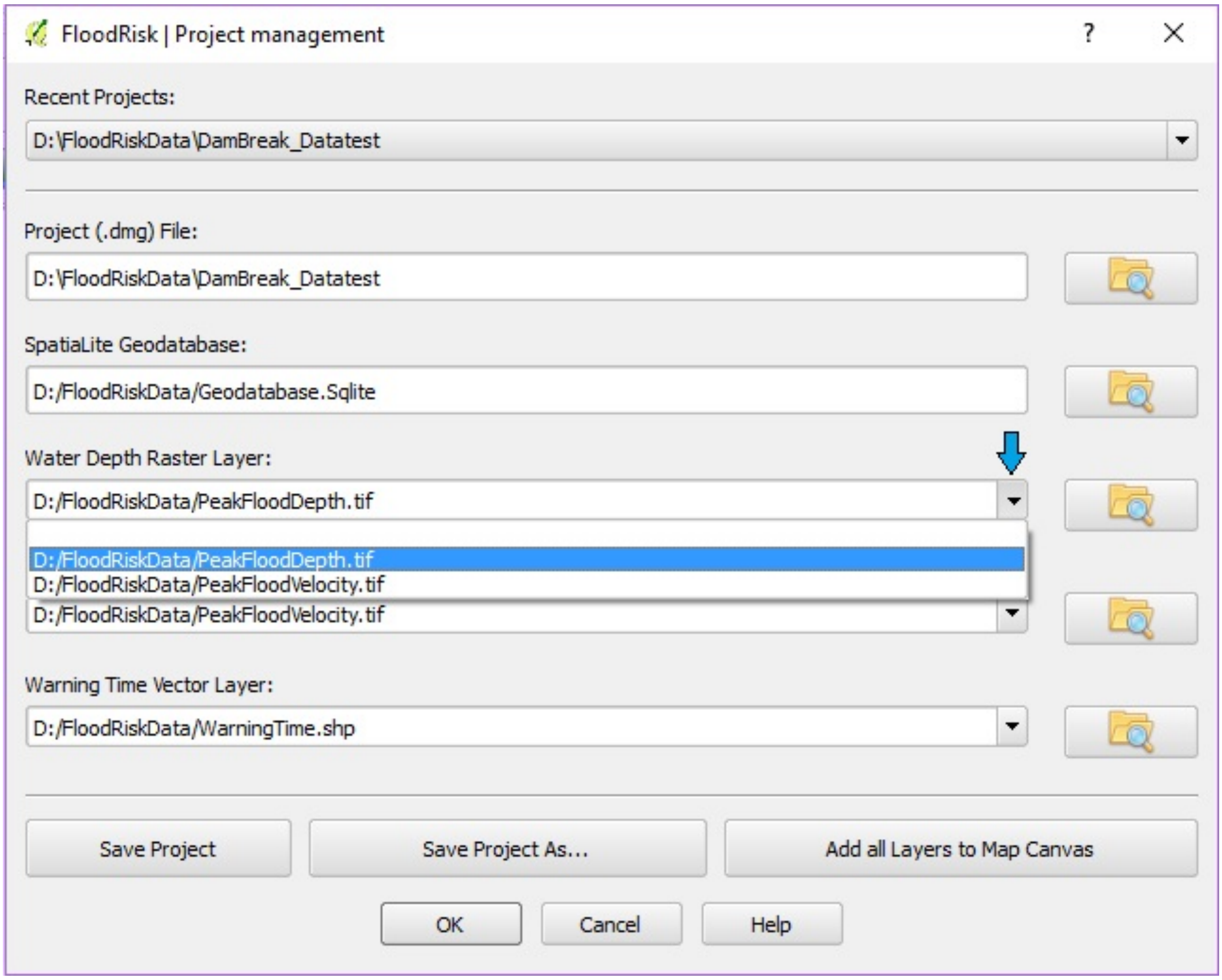


Figure 12 - Hazard data upload

Hence, you can save the project by clicking the button **"Save Project"**.

Then press the **"Add all Layers to Map Canvas"** button in order to visualize in QGIS map canvas all the layers that are part of the created project (Fig.13).

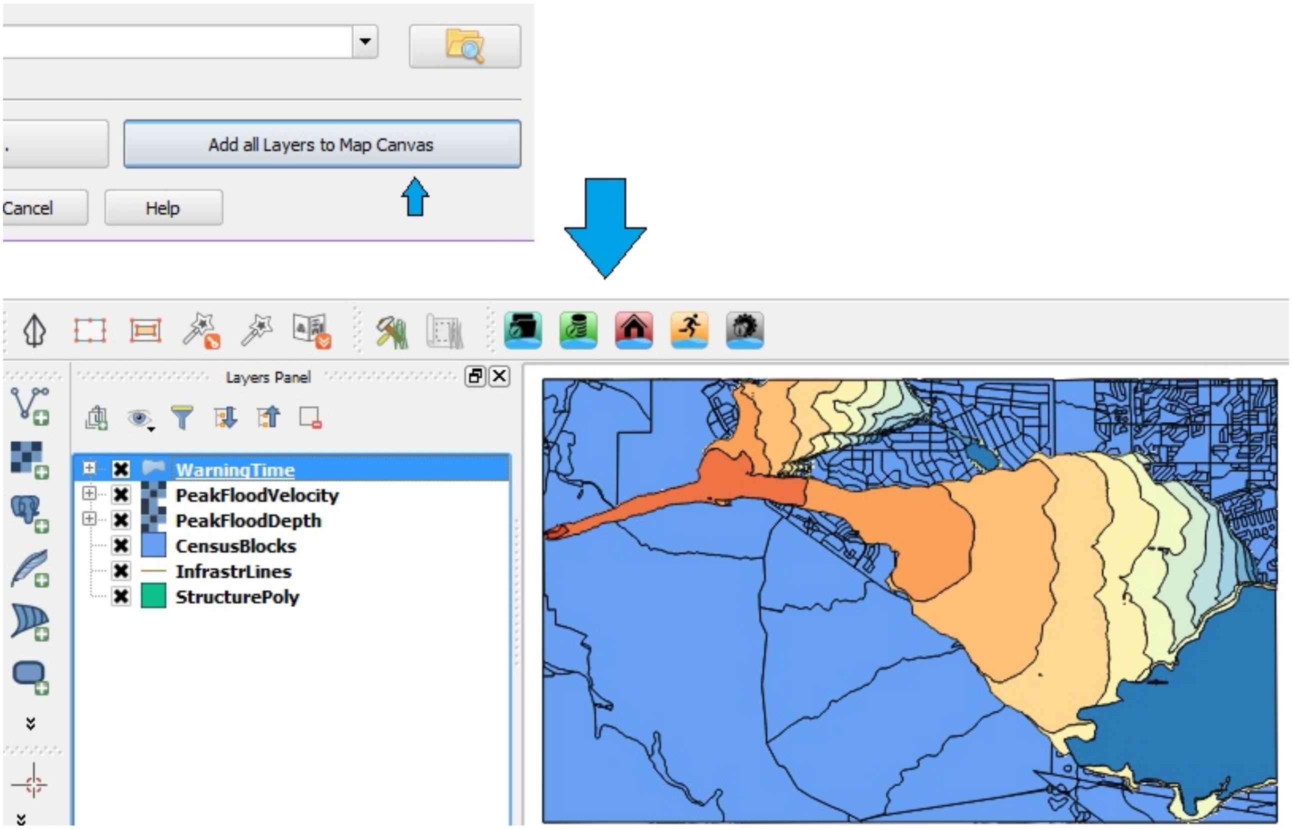


Figure 13 - Adding Layers to Map Canvas

Note: *If you chose first the Water Depth Raster Layer, the system automatically suggests a name for the project.*

Note: *In case you want to make a copy of the project you can use the button* ***"Save Project as.."****. If you want to open an existing project, you can choose it from* ***"Recent Projects"*** *or by clicking the search button next to* ***"Project"****.*

Now you can easily calculate the **direct economic damage**. First, click on  Direct Economic Damages icon of the *FloodRisk* toolbar in order to open **Direct Economic Damages window**, (Fig. 14).

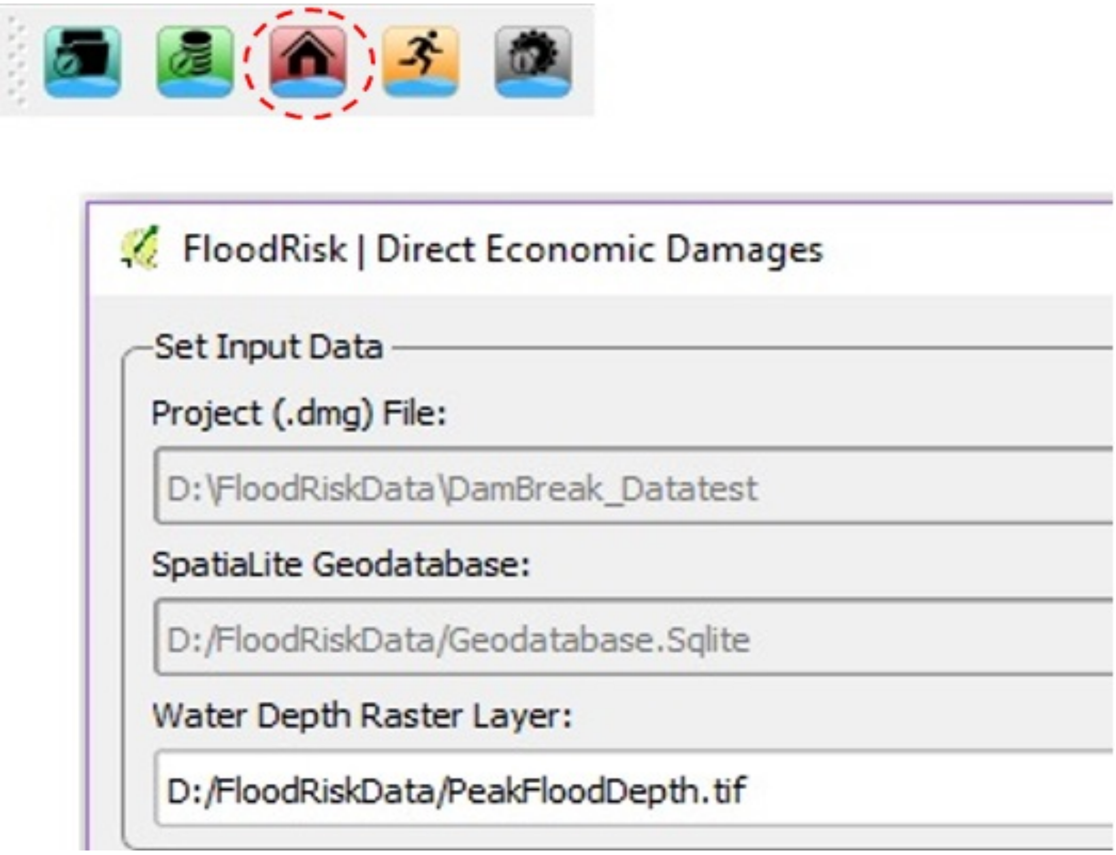


Figure 14 - Direct Economic Damages Frame opening by toolbar

In this window, you can choose the type of depth-damage curve that you want to use and you can run the simulation in order to obtain the economic damages. Now, choose e.g. “HazusModel” *depth-damage curve*, by clicking on the down arrow of the *Set Depth-Damage Curves Type Combobox* (Fig.15).

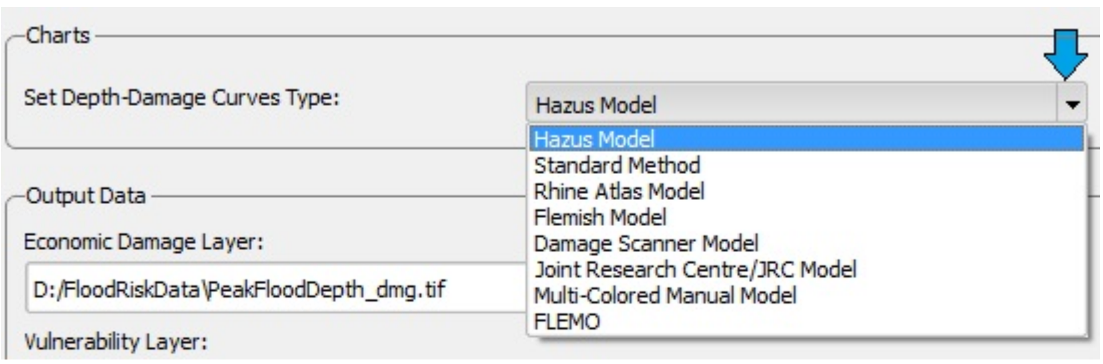


Figure 15 - Setting the Depth-Damage Curves

Next, you can run the simulation by clicking the button **“Run Simulation”**. Then press the **“Add all Layers to Map Canvas”** button in order to visualize in QGIS all the results layers (Fig.16).

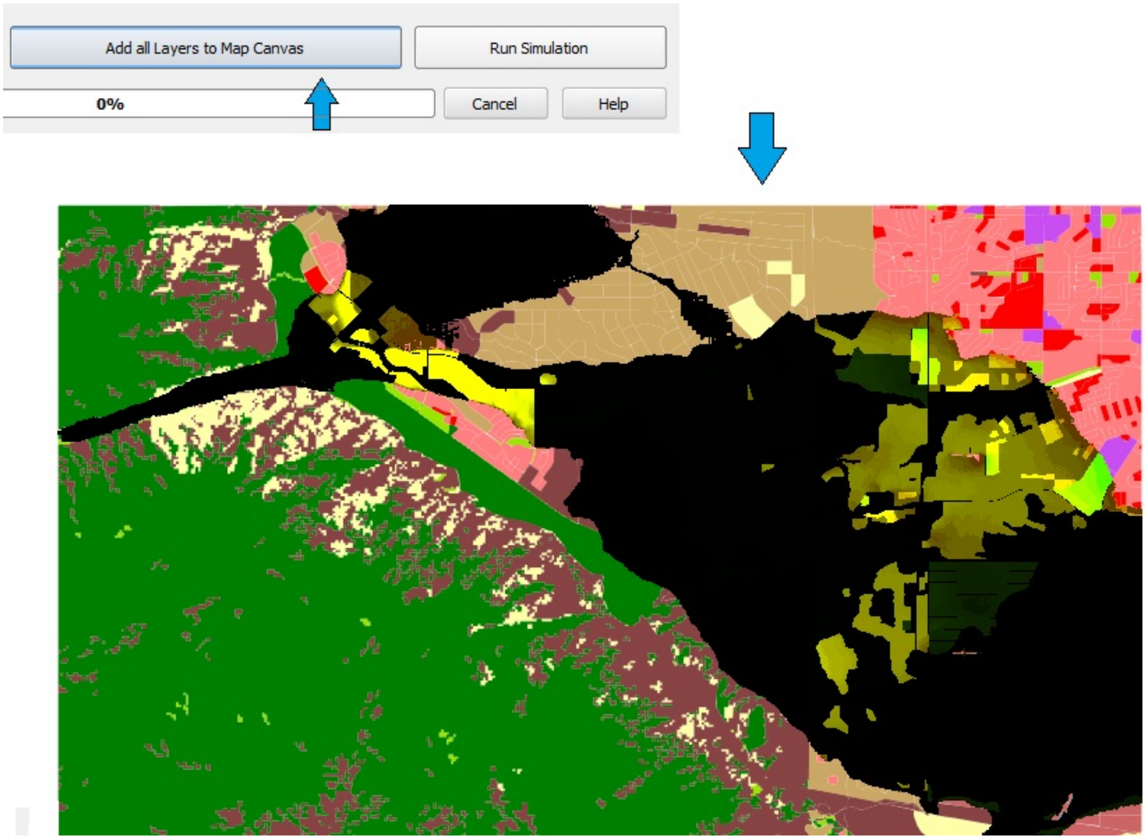


Figure 16 - Adding Layers to Map Canvas/ Results Layers

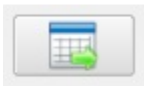
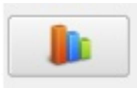
Finally, in order to check the results in **.csv* format click on  button next to the *Global Summary Table Combobox*: a table containing the results grouped by class of asset will be showed (Fig.17). In order to see the *Histogram* of the results click on  button next to the *Global Summary Table Comobox* (Fig.18).

Table Viewer:C:/Users/lulya/Desktop/New folder\PeakFloodDepth_dmg.csv

Table preview

	Code	Description	Valstr_Euro	ValCon_Euro	DamageStr_Euro	DamageCon_Euro
1	11100	Continuous Urban Fabric (S.L. > 80%)	0	0	0	0
2	11210	Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)	7879600	3939800	2808600	1874200
3	11220	Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%)	203191000	101595500	65918700	40930000
4	11230	Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)	1614429100	807214600	653092600	440572100
5	11240	Discontinuous Very Low Density Urban Fabric (S.L. < 10%)	0	0	0	0
6	11300	Isolated Structures	48236300	72354500	14859800	28146700
7	12100	Industrial, commercial, public, military and private units	342799000	1199796600	59665400	556797500
8	12210	Fast transit roads and associated land	95509900	3820500	0	0
9	12220	Other roads and associated land	22413400	896600	0	0
10	12230	Railways and associated land	0	0	0	0
11	12300	Port areas	0	0	0	0
12	12400	Airports	0	0	0	0
13	13100	Mineral extraction and dump sites	0	0	0	0
14	13300	Construction sites	0	15069000	0	8439700
15	13400	Land without current use	0	0	0	0

Cancel

Figure 17 - Global Summary Table: Economic Damages

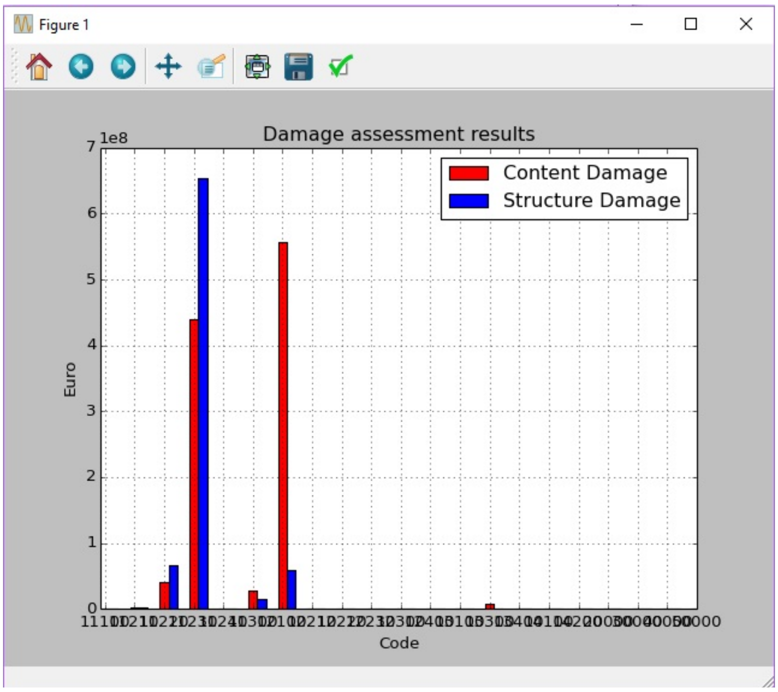
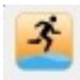


Figure 18 - Histogram of Economic Damages

Next, you can estimate the **loss of life**. First, click on  **Loss of Life Assessment icon** of the *FloodRisk* toolbar in order to open **Loss Of Life Assessment window**, (Fig. 19). This window allows you to assess the population at risk and number of potential fatalities.

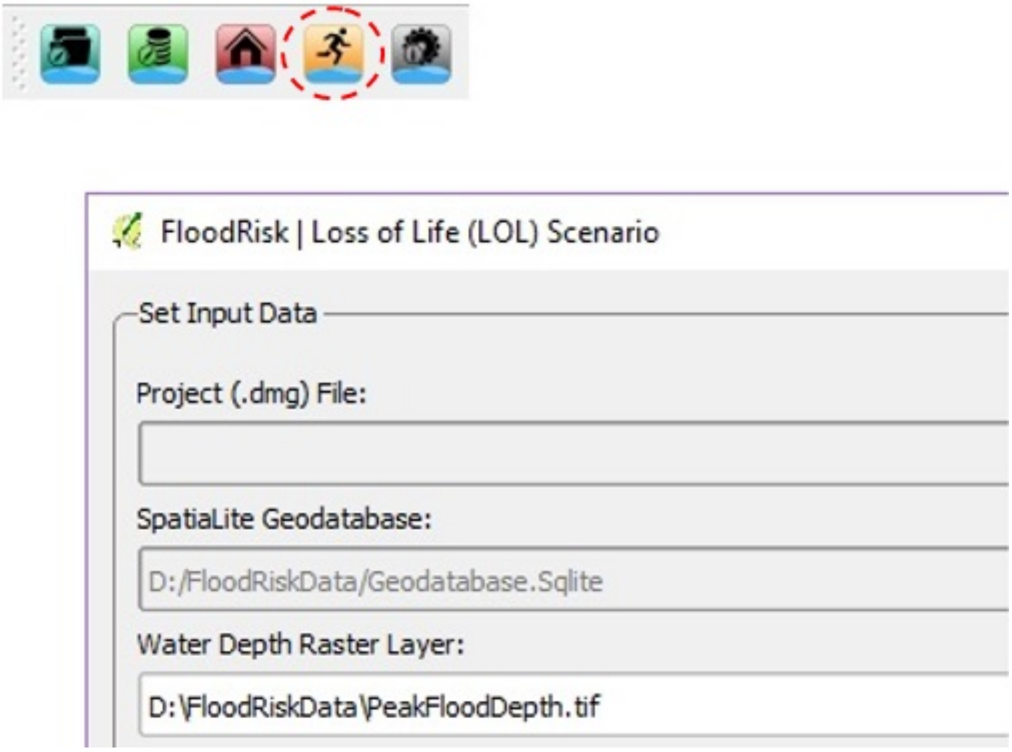


Figure 19 - Loss of Life Assessment Frame opening by toolbar

In this tutorial, you can choose the **Dam Failure Scenarios (DHS)** methodologies in the *Set Methodology Box*. Then, set the understanding by clicking on the down arrow of the *Set Understanding Combobox*, and choose "Precise" (Fig.20). In this case we have hypnotized that the degree of population understanding of the event is high, (e.g. the event occurs during the day), and, therefore, the potential losses is mitigated by this contributing parameter.

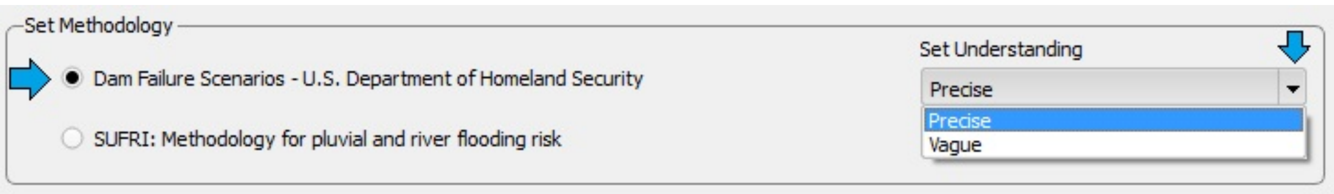


Figure 20 - Loss of Life Assessment Methodology

Next, press the **"Run Simulation"** button in order to obtain the results and **"Add all Layers to Map Canvas"** button in order to visualize in QGIS the results layer (Fig.21).

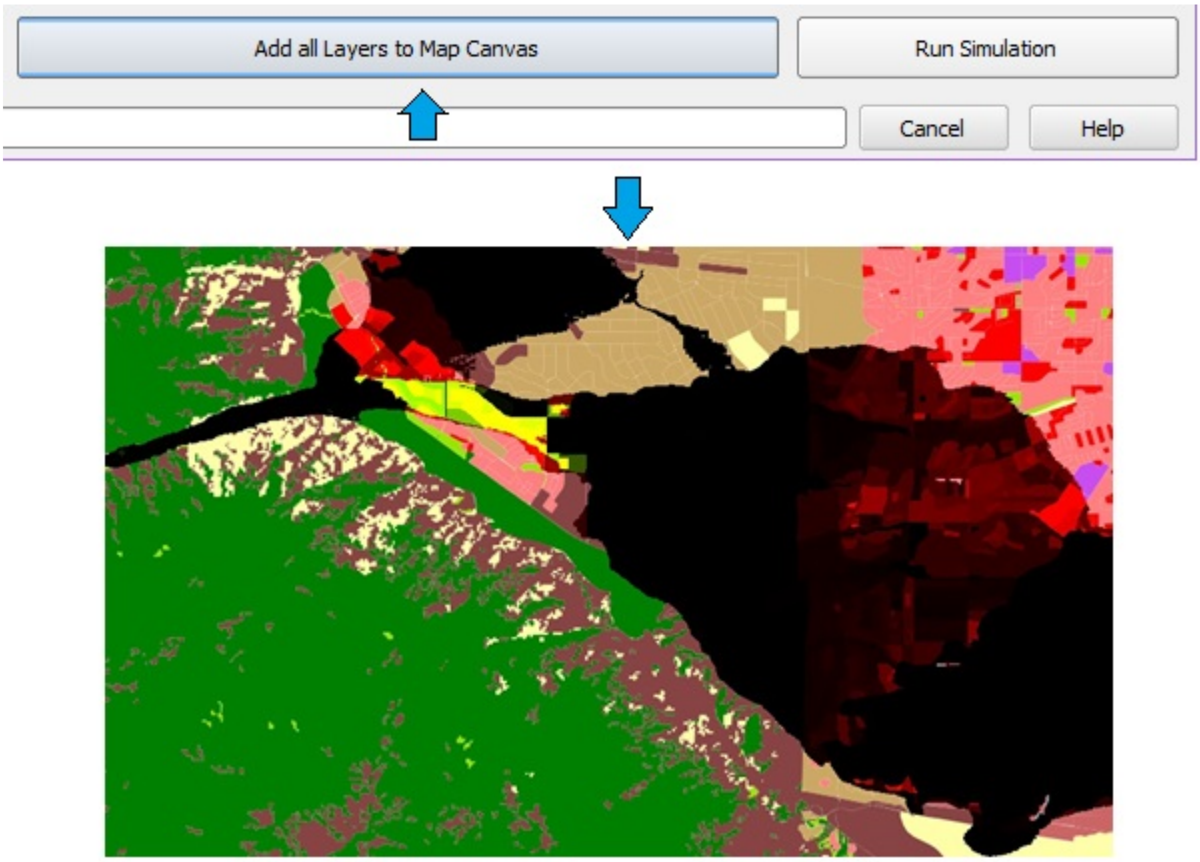


Figure 21 - Adding Layers to Map Canvas/ Resulting Layer

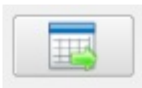
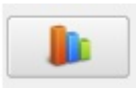
Finally, in order to see the results in **.csv* format click on  button next to the *Global Summary Table Combobox*: a table containing the results grouped by *Range of Water Depth* will be showed (Fig.22). In order to see the *Histogram* of the results click on  button next to the *Global Summary Table Comobox* (Fig.23).

Table Viewer:D:\FloodRiskData\PeakFloodDepth_pop.csv

Table preview

	Range Water Depth (m)	Flooded Area (m2)	Resident Pop. at Risk	Seasonal Pop. at Risk	Total Population at Risk	Loss of Life
1	0.0-1.0	14791061	10245	3001	13246	6
2	1.0-2.0	17769334	12976	977	13953	7
3	2.0-3.0	10419689	2113	591	2704	11
4	3.0-4.0	4260025	499	446	945	86
5	>4	4251135	2905	5802	8707	5203
6	Total	51491244	28738	10817	39555	5313

Cancel

Figure 22 - Global Summary Table: Loss of Life (LOL)

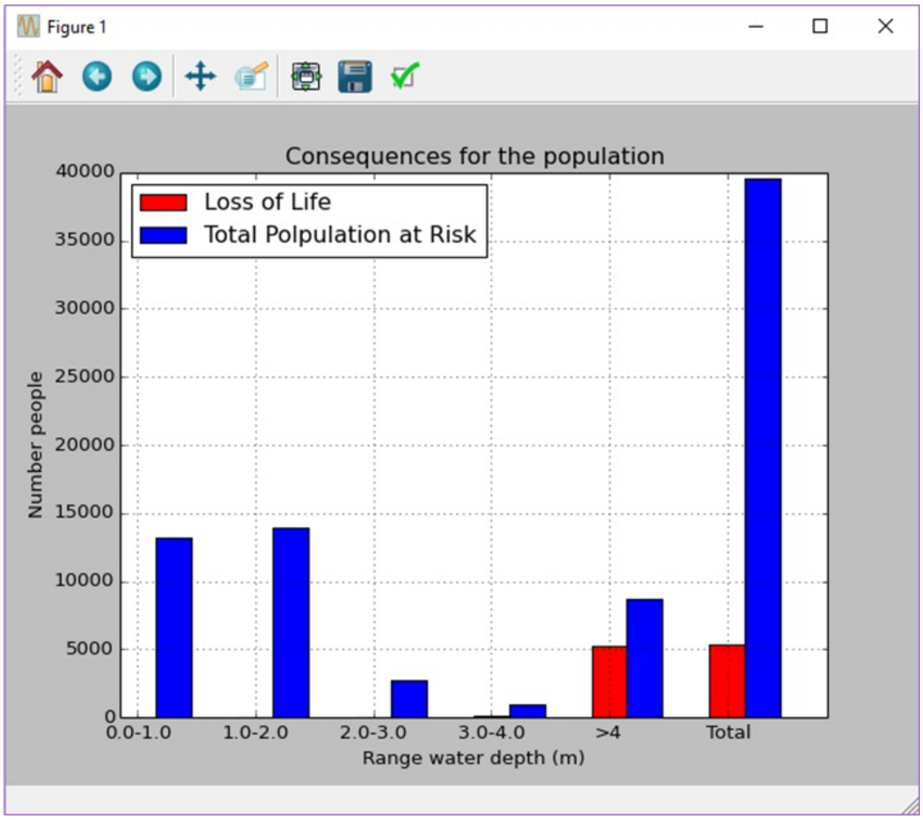


Figure 23 - Histogram of LOL

7.4 Results

The results of the *FloodRisk* plug-in are able to support decision-making regarding the prioritization of risk prevention measures in order to optimize investments and regarding the evaluation of different mitigation actions, and insurance agencies in order to improve the estimation of risk-base premium for diverse spatial areas on the basis of a increase understanding of expected compensation payments

Economic damages results

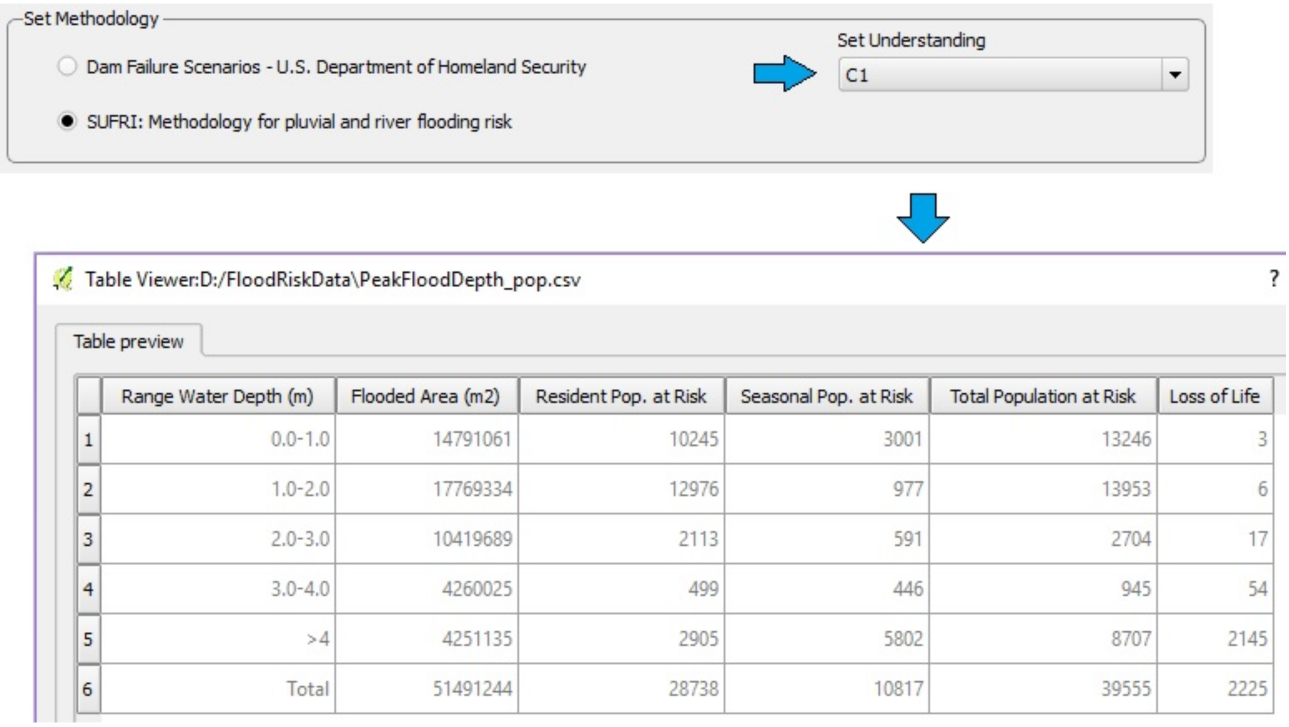
The *FloodRisk* plug-in with the help of maximum depth, structure attributes (value, occupancy type, damage category and foundation height) and the related user- defined damage curves, calculate the percentage of direct- physical losses of structure and contents. It is worth noting that different economic sectors and type of buildings are definable by occupancy type and damage category and for each sector and its assets, user can define a separate damage curve. As showed in Fig.s16 and 17, the results regarding the economic damages are represented by a map of damage, a map of vulnerability and a damage table. The map of damage contains the economic damage expected for the structures and their content (Euro per square meter). The map of vulnerability contains the vulnerability for structures and contents as a % of damage with respect to a pre-defined maximum damage value . This value can be expressed as either replacement cost or depreciated/repair cost on the basis of stakeholders needs. In the damage table, there are all the land use classes and for each class the plugin calculates the damages for structure and content.

Loss of Life Assessment results

Hydraulics data such as arrival time of the flood, maximum depth of water are important in life loss assessment. Also, precaution measures like warning system, coordination and information of population play an important role in the mitigation of loss of life (see section Tips and Tricks). The results regarding the Loss of Life Assessment (Fig.21 and Fig.22) are represented by a map of population at risk, a map of potential loss of life and a summary table. The map of population at risk contains the population density at risk and the number of potential fatalities is obtained by multiplying population at risk time the fatality rate (people per sq.km of land area). In the table (Fig.22) these results are grouped by Range of Water Depth.

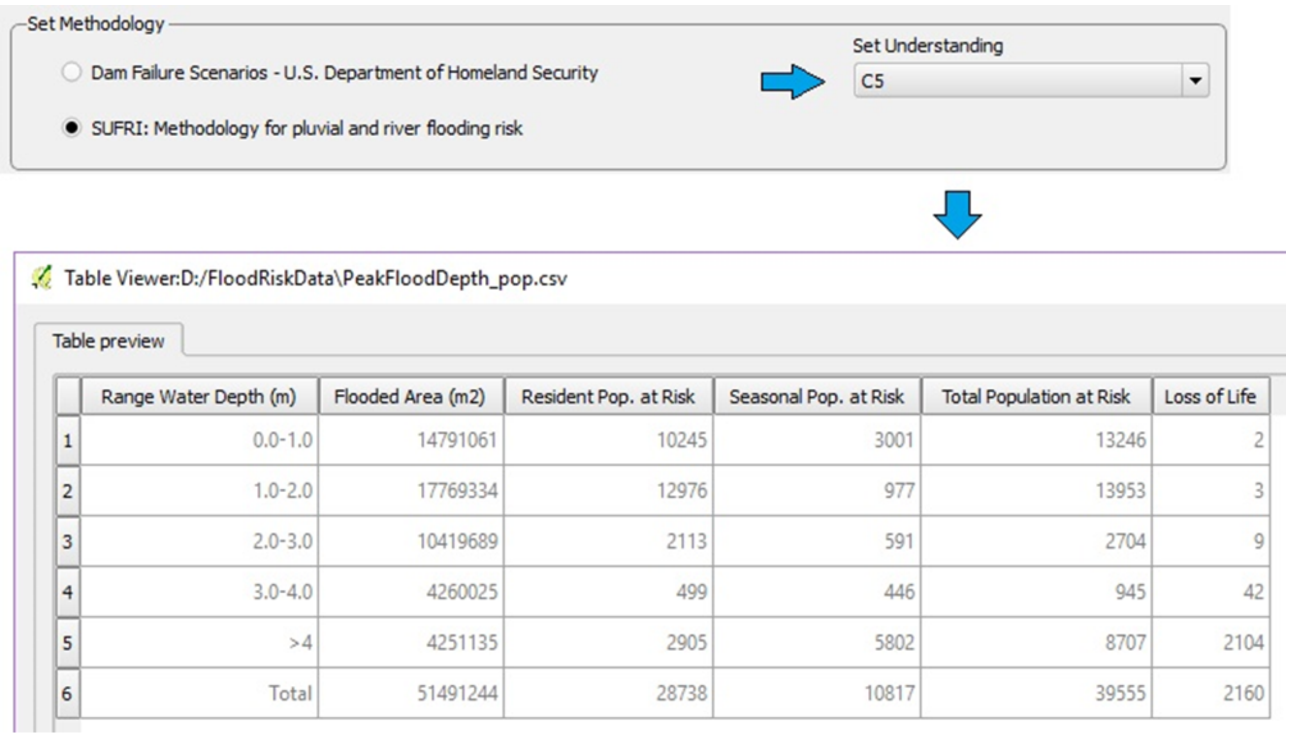
7.5 Tips and Tricks

The performed consequence analysis could be considerably affected by the non-structural mitigation measures utilized. Indeed, if you estimated the potential loss of life with the SUFRI methodology [7], the results that you will obtain depend on the category of understanding, i.e. degree of population readiness, that you will set. There are ten categories (C1 to C10), see Table 1, depending on the existence of non-structural measures public education on flood risk, warning and communication system, and, coordination between emergency agencies and authorities. In the following we have utilized several categories set checking how the final results, in terms of loss of life, has changed. In Fig.24, where category is set to C1 (no public education; no warning systems; no coordination and communication), the total number of losses is 2225. In Fig.25, C5 is set as category (no public education; EAP is already applied; coordination exists; no communication) and, hence, a slightly decrease on the number of loss of lives, i.e. 2160. Finally, in Fig.26 a great decrease of the number of loss of lives, i.e. 709, is obtained using the category C10 (public education; EAR is already applied; high coordination and communication).



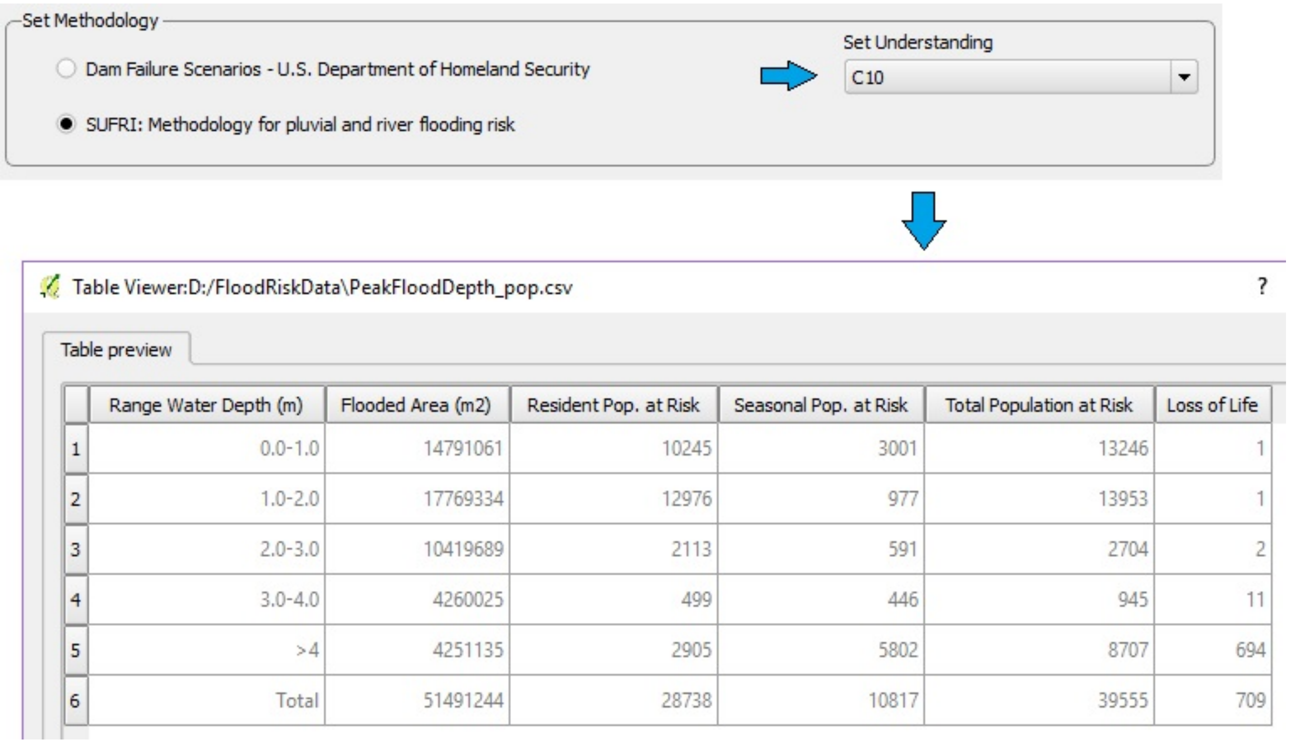
	Range Water Depth (m)	Flooded Area (m2)	Resident Pop. at Risk	Seasonal Pop. at Risk	Total Population at Risk	Loss of Life
1	0.0-1.0	14791061	10245	3001	13246	3
2	1.0-2.0	17769334	12976	977	13953	6
3	2.0-3.0	10419689	2113	591	2704	17
4	3.0-4.0	4260025	499	446	945	54
5	>4	4251135	2905	5802	8707	2145
6	Total	51491244	28738	10817	39555	2225

Figure 24 - Loss of life results using the understanding category C1



	Range Water Depth (m)	Flooded Area (m2)	Resident Pop. at Risk	Seasonal Pop. at Risk	Total Population at Risk	Loss of Life
1	0.0-1.0	14791061	10245	3001	13246	2
2	1.0-2.0	17769334	12976	977	13953	3
3	2.0-3.0	10419689	2113	591	2704	9
4	3.0-4.0	4260025	499	446	945	42
5	>4	4251135	2905	5802	8707	2104
6	Total	51491244	28738	10817	39555	2160

Figure 25 - Loss of life results using the understanding category C5



	Range Water Depth (m)	Flooded Area (m2)	Resident Pop. at Risk	Seasonal Pop. at Risk	Total Population at Risk	Loss of Life
1	0.0-1.0	14791061	10245	3001	13246	1
2	1.0-2.0	17769334	12976	977	13953	1
3	2.0-3.0	10419689	2113	591	2704	2
4	3.0-4.0	4260025	499	446	945	11
5	>4	4251135	2905	5802	8707	694
6	Total	51491244	28738	10817	39555	709

Figure 26 - Loss of life results using the understanding category C10

Acknowledgments

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