4th International Symposium on Flood Defence:
Managing Flood Risk, Reliability and Vulnerability
Toronto, Ontario, Canada, May 6-8, 2008

Integrating Hydraulic and Economic Analysis for Selecting Flood Protection Measures in the Context of Climate Change

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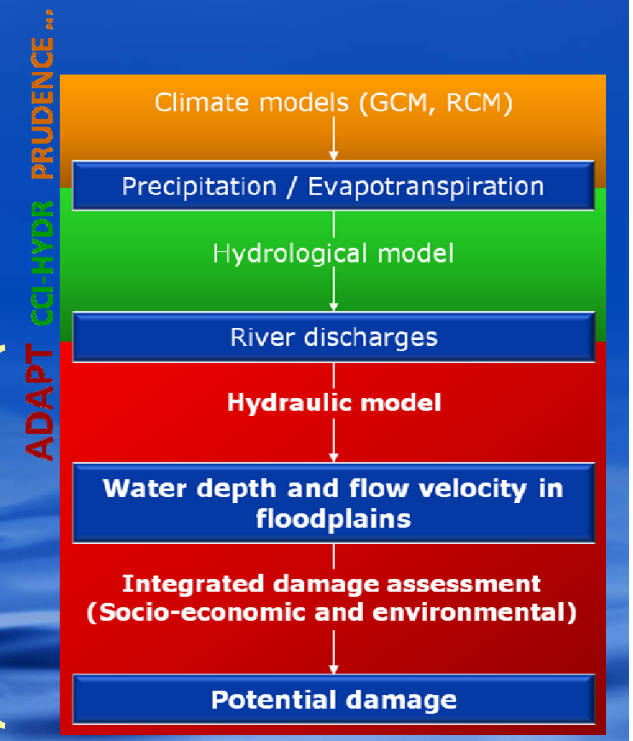
INTRODUCTION

- Climate models predict increases in peak discharges in rivers
  - ➔ Need for flood protection measures
  - ➔ Need for Decision Support Systems for their selection

- In this context, a new high precision tool is developed
  - ➔ Hydraulic and economic analysis integrated by geomatic methods
  - ➔ Integrated assessment of possible flood protection measures

The national Belgian project "ADAPT"
TOWARDS AN INTEGRATED DECISION TOOL FOR ADAPTATION MEASURES



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HYDRAULIC MODEL

- Modeling system named WOLF fully developed at the HACH unit

Continuous developments based on multiple PhD theses

WOLF AG

Automatic parameters calibration

WOLF HYDRO

Hydrological runoffs

WOLF 1D

Rivers networks

WOLF 2D

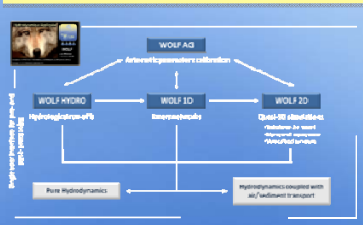
Quasi-3D simulations

- Turbulence *k-ε* model
- Moment of momentum
- Vertical bed curvature

Single user interface for pre- and post- processing

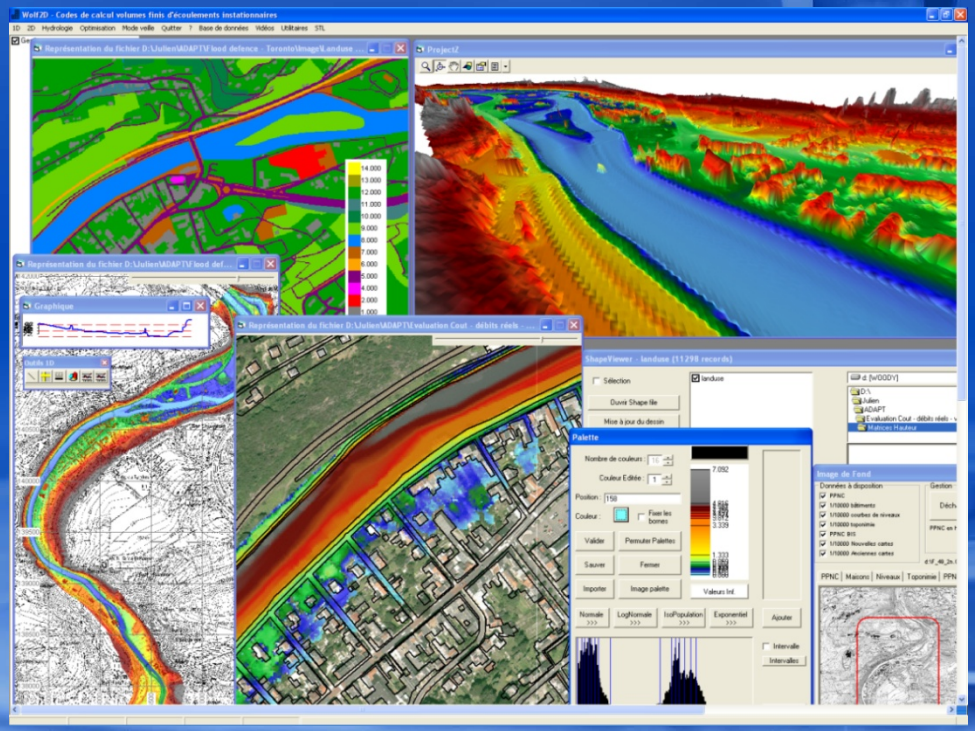
Pure Hydrodynamics

Hydrodynamics coupled with air/sediment transport

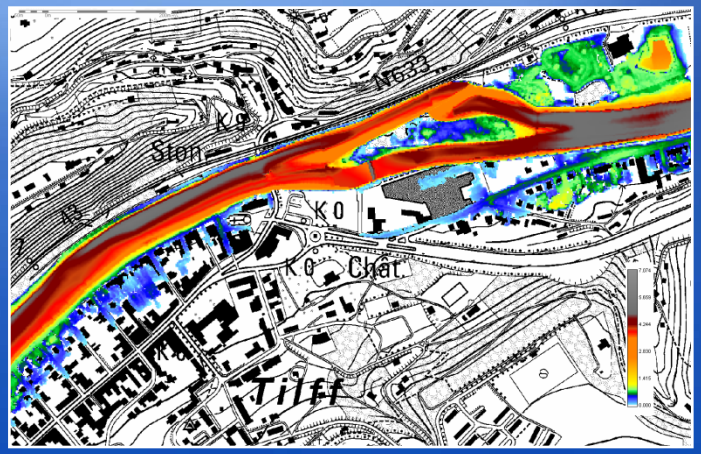


• WOLF2D module

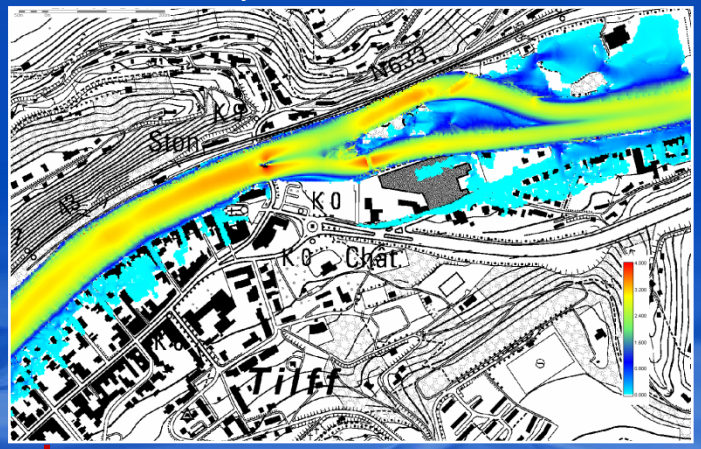
- 2D hydrodynamic results are suitable inputs for the subsequent micro scale integrated analysis
- Handling of GIS data and management of layers ,…



Water depth [m]



Flow velocity [m/s]



Combination of complete shallow water equations and very accurate geographic data

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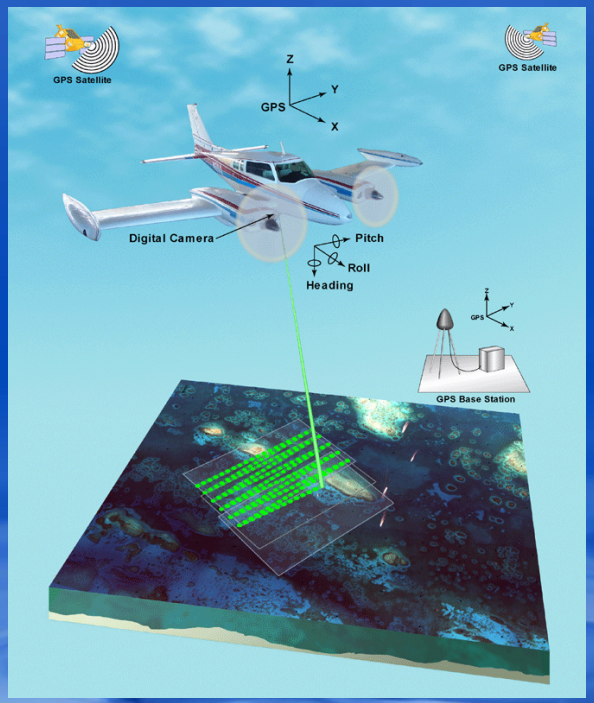
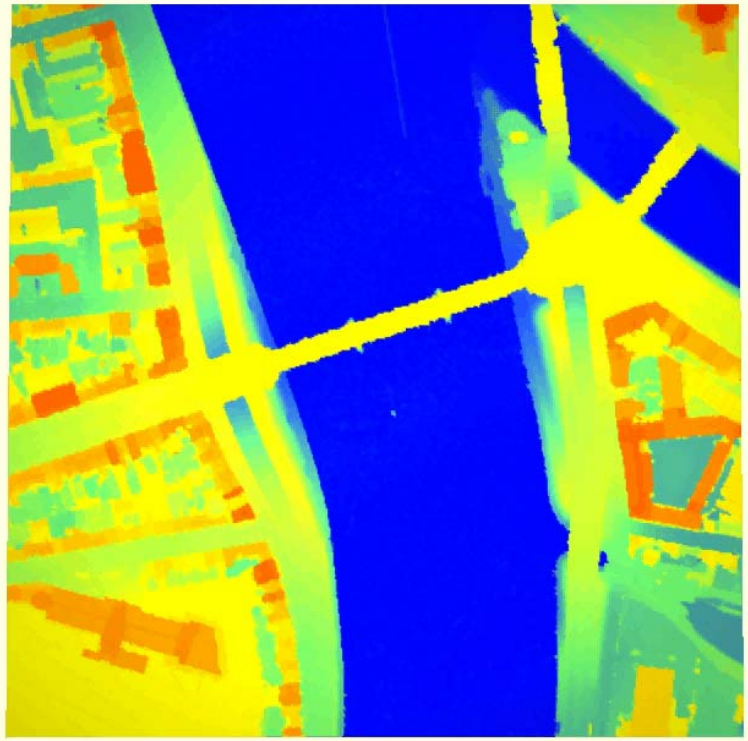
GEOGRAPHIC DATA

• LiDAR - *Light Detection And Ranging*

- Remote sensing tool, DSM generation
- Similar technique as RADAR, but laser pulses



Geometric characteristics
- Altitude accuracy 15 cm
- Grid 1 x 1 m



DSM + Bathymetry + Aerial imagery texture

• Land use map (I)

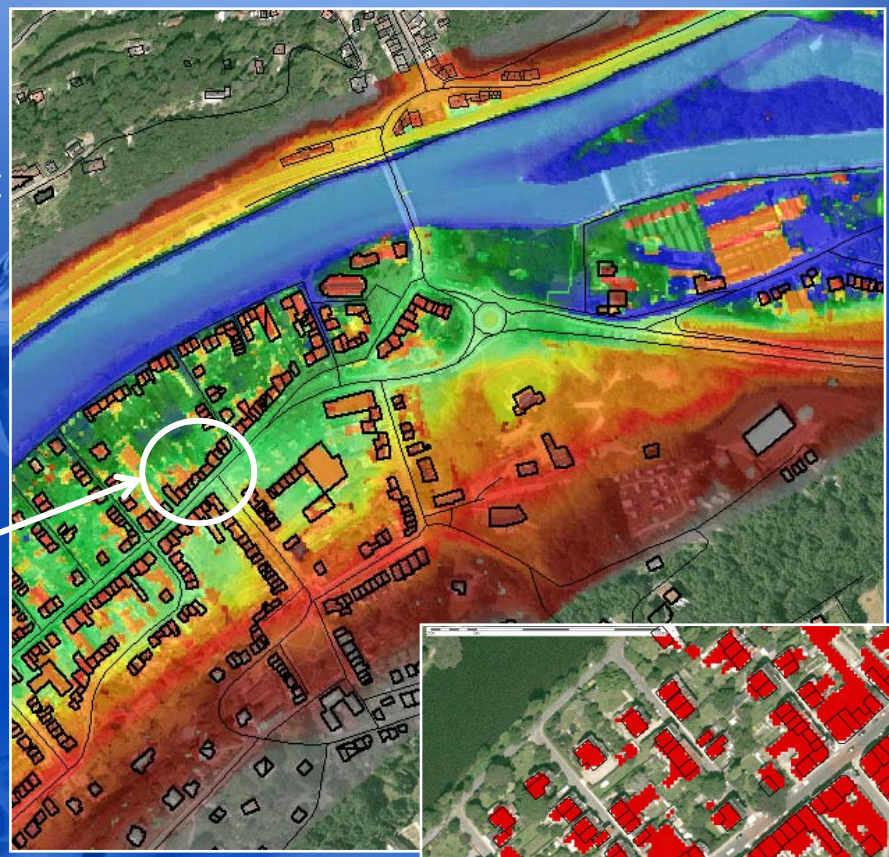
Top10v-GIS - National Geographic Institute IGN

- Vector data : collection of points, lines, polygons from IGN in GIS file format (.shp)
- Scale 1:10000
- 18 layers (administration data, altimetry, electricity, land use, structure,…)

Class of object selection from Top10v-GIS

- Residence
- Industry
- Road network
- Agriculture (crops, field)
- Forestry

LiDAR Surface elevation + PICC vector



• Land use map (II)

PICC - Ministry of Facilities and Transport

- Vector data
- Cornice elevation

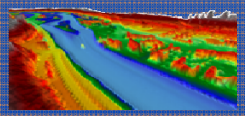
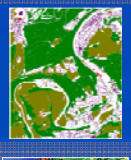
➔ identify each adjoining houses

• Land registry

- Location of individual buildings and plots
- Economic information
- Value of the assets

Top10v-GIS (red)
PICC (black vector)

- Complementary data sources

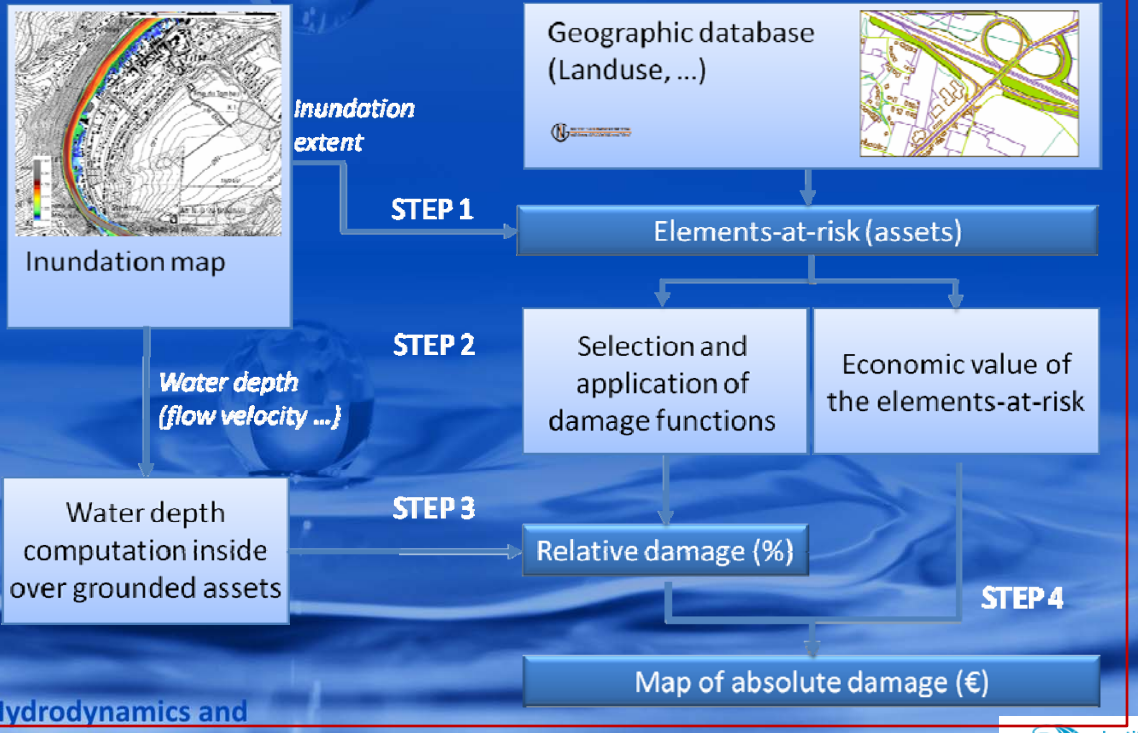
Data	Format	Geometric	Semantic	Feature
LiDAR 	Raster	Good	Poor	Accurate elevation (DSM)
Top10v-GIS 	Vector	Good	Good	Very rich land use data
PICC 	Vector	Good	Middle	*E.g.* cornice height
Land registry	Vector	Poor	Good	Mainly economic information

METHODOLOGY

Flood risk definition:

FLOOD RISK = sum (probability * consequences)

Probability	Consequences (actual predicted damage)		
Probability	**Exposure**	**Elements-at-risk**	**Vulnerability**
(return period)	(extent, depth, velocity)	(people, buildings, networks, eco-systems ...)	(susceptibility, adaptive capacity, resilience, ...)



Automatic four-step methodology

Tangible and direct consequences

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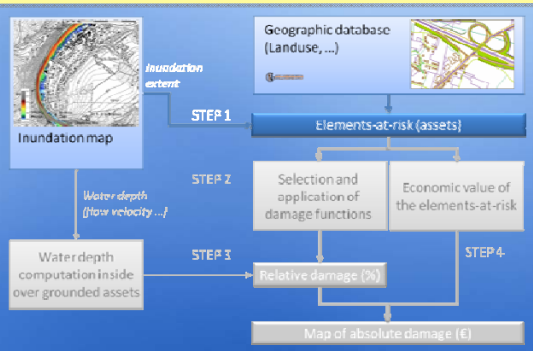
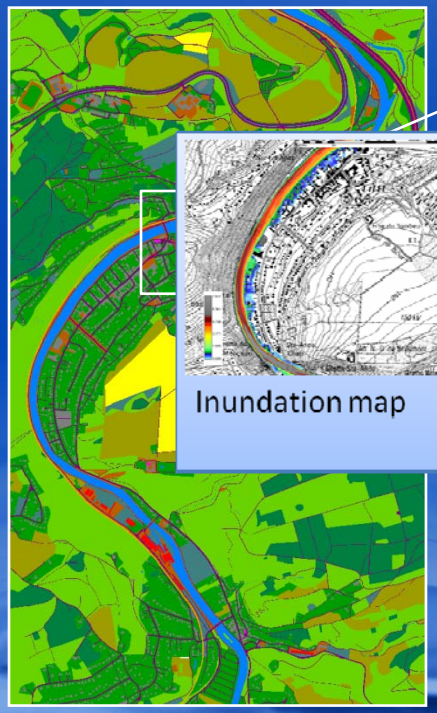
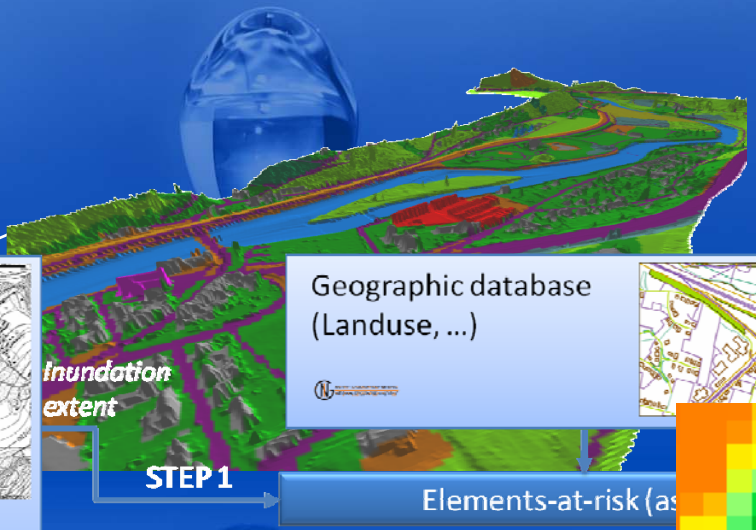


- Combination of land use map and inundation extent

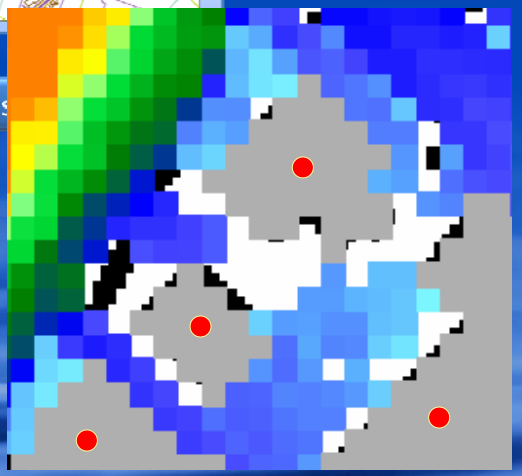


Crop
Field
Lawn
Brushwood
Conifer
Broad-leaved tree
Hydrographic
Nude Ground
Railway
Road network
Church
Industry
House

Inundation map



Elements-at-risk identification (Houses)



Mesh size : 2 x 2m

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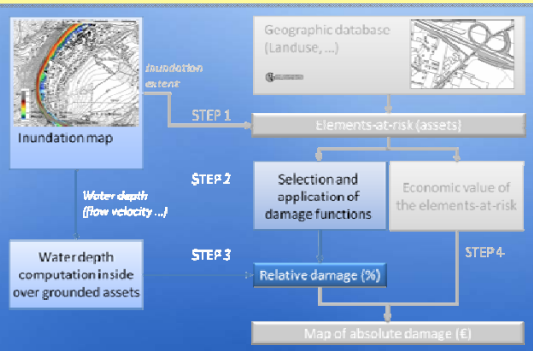
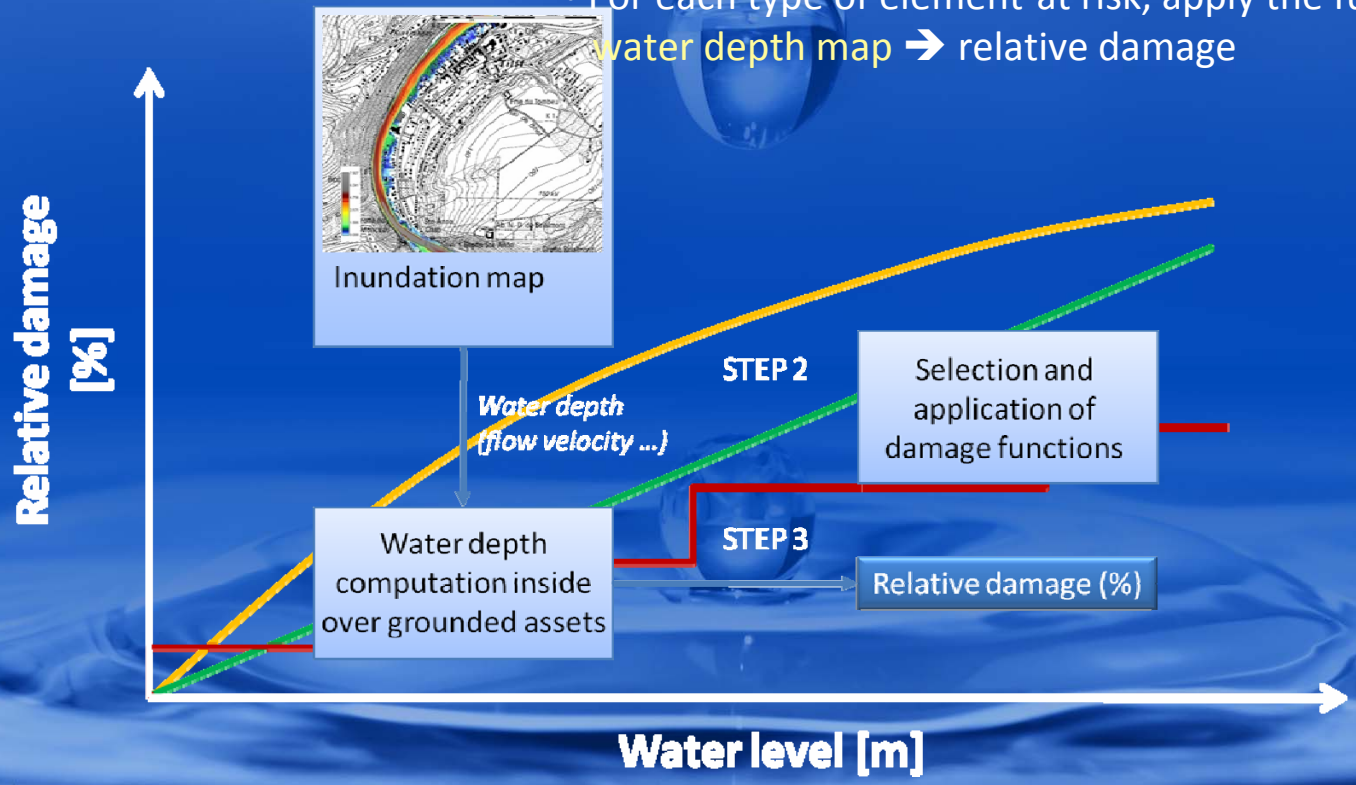
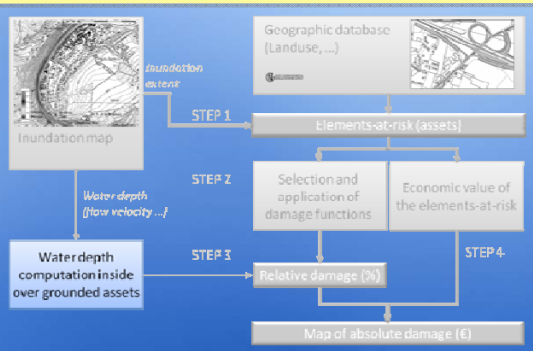


• Damage functions

- Various kinds of functions exist in literature
  ➔ the selection has to be done very carefully
- For each type of element-at risk, apply the function on water depth map ➔ relative damage

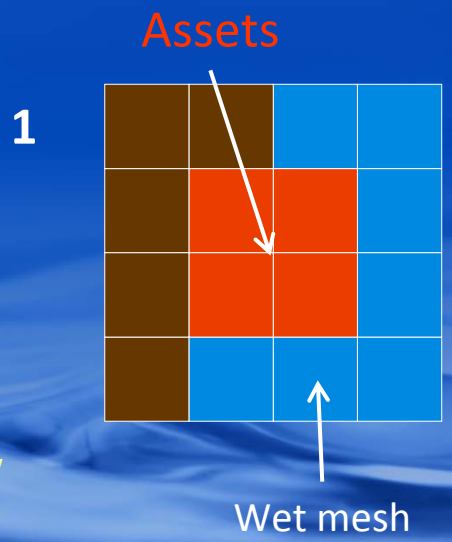


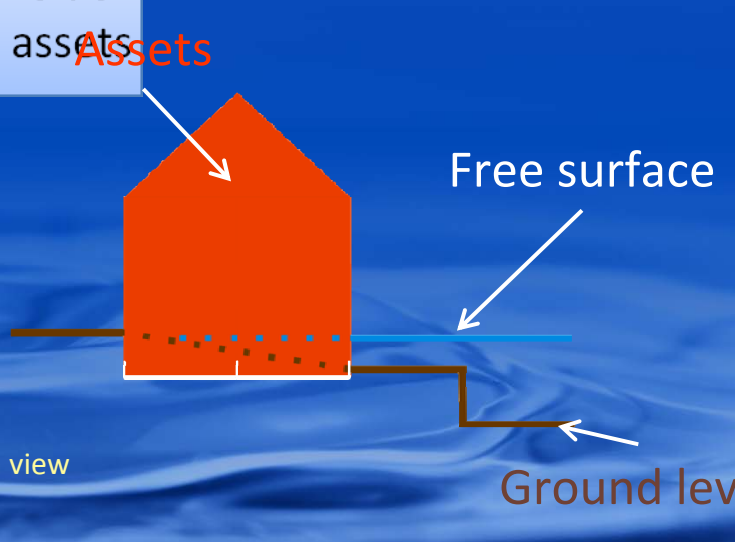


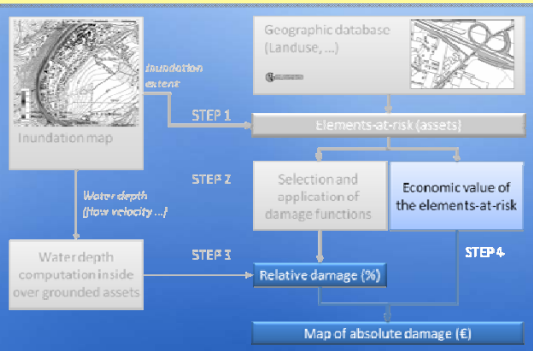
- Water depth computation inside over grounded assets

1. Average wet meshes in the vicinity of the object
2. Ground and fre side the object

Water depth computation inside over grounded assets



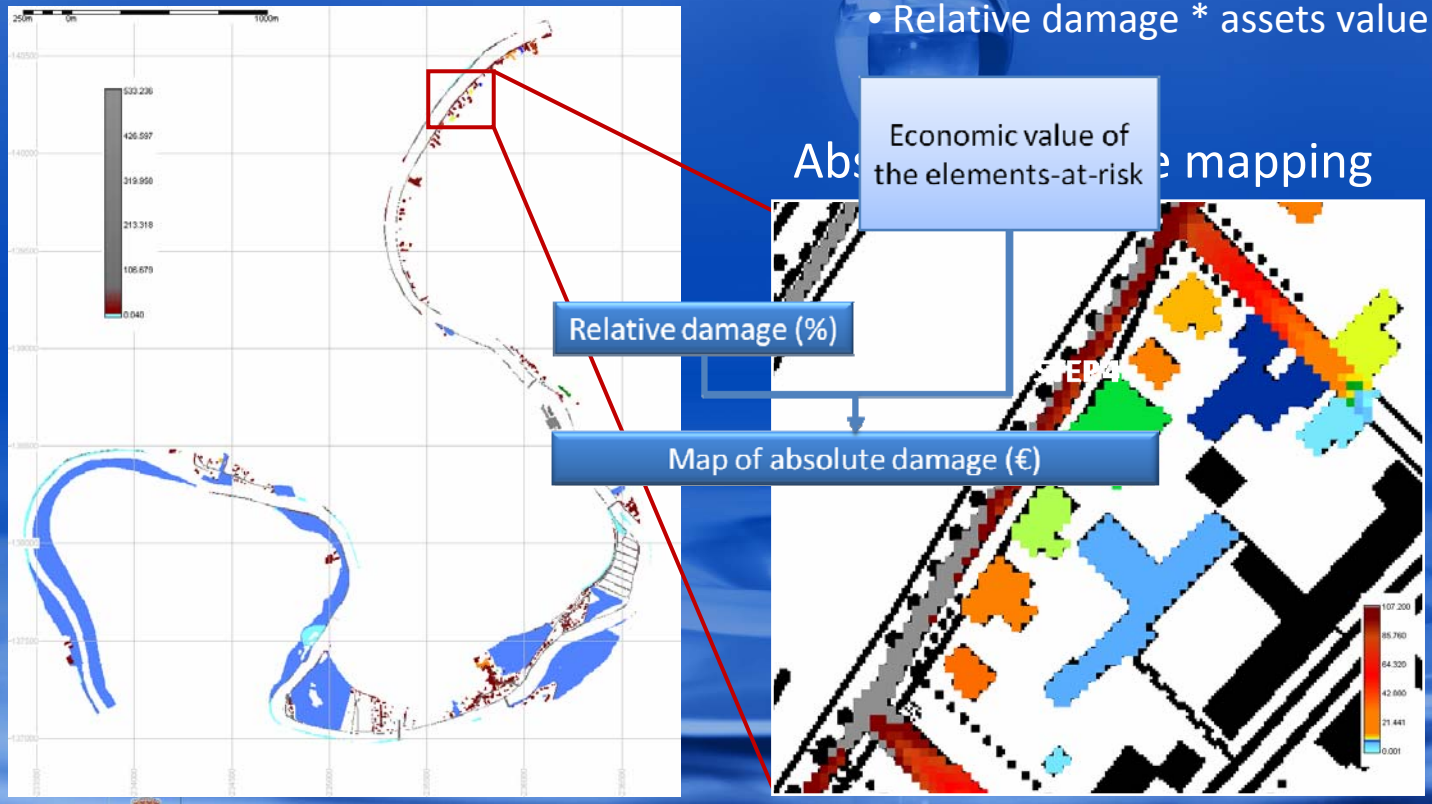




• Absolute damage assessment

• Specific value determination
Value of the assets by surface unit

• Relative damage * assets value



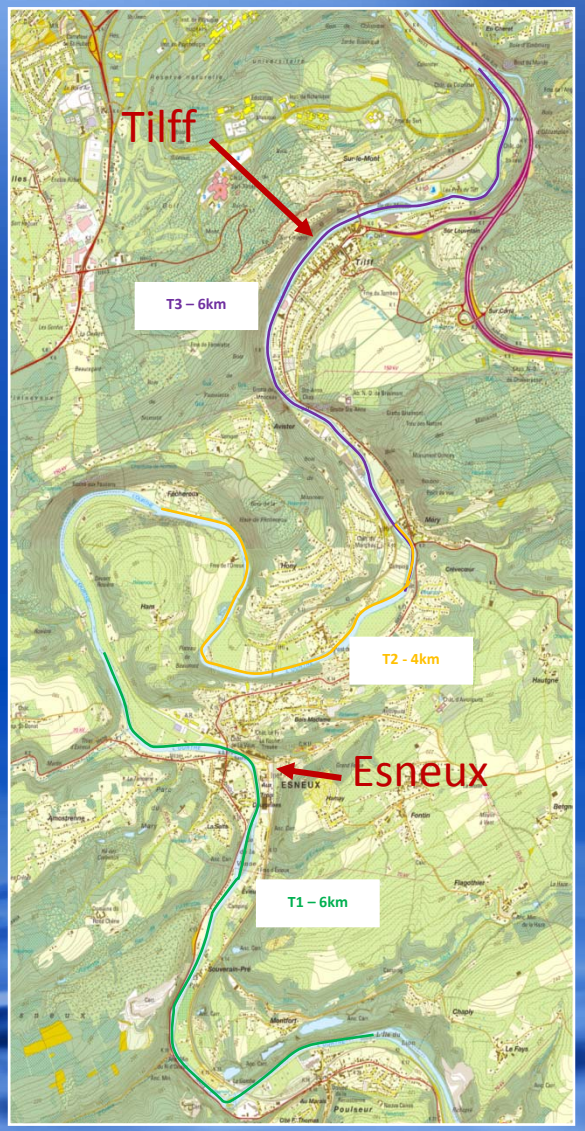
REAL FLOOD EVENTS

- Case studies : application of the damage evaluation models chain

1. Hydraulic WOLF2D model has been validated for many years (benchmarks and field studies)
2. Elements-at-risk identification
3. Loss estimation model (*disaster fund* - give compensation)

- River Ourthe – Meuse basin
  - 3 reaches (16 km of river with 2m modeling mesh size)
  - 4 major flood events :
    - 1993 – 742 m³/s
    - 1995 – 520 m³/s
    - 2002 – 570 m³/s
    - 2003 – 508 m³/s

Case studies



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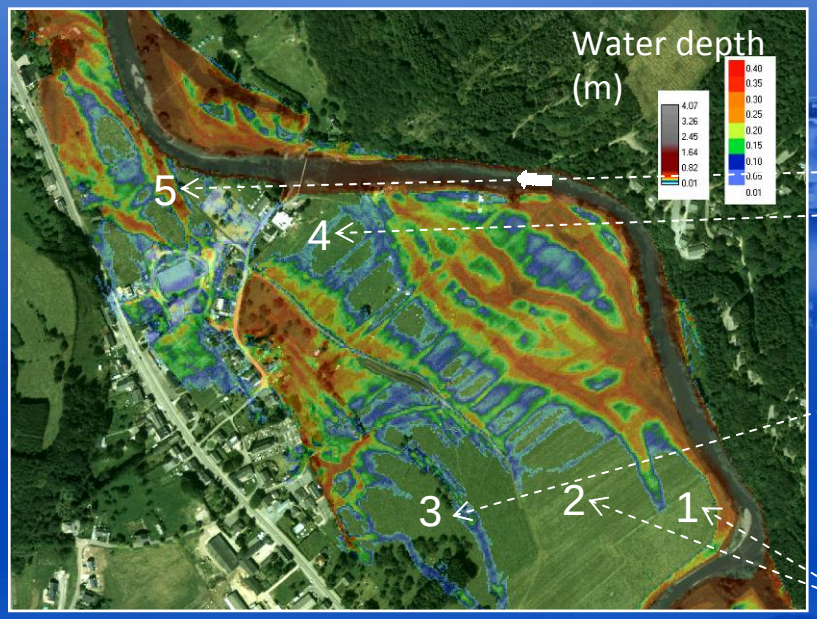
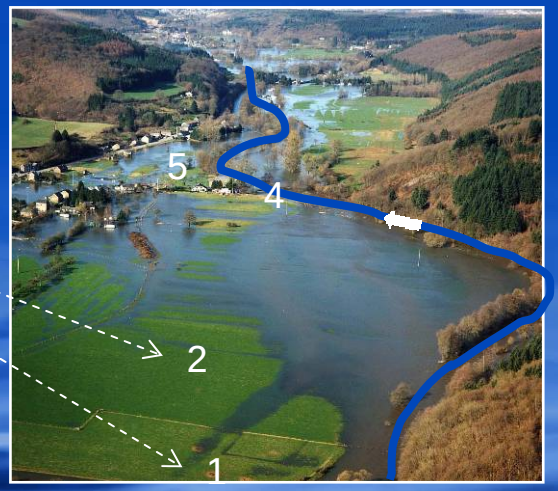
• Validation of the flow model based on past events



Simulated flood extent and water depth

Observed flood extent

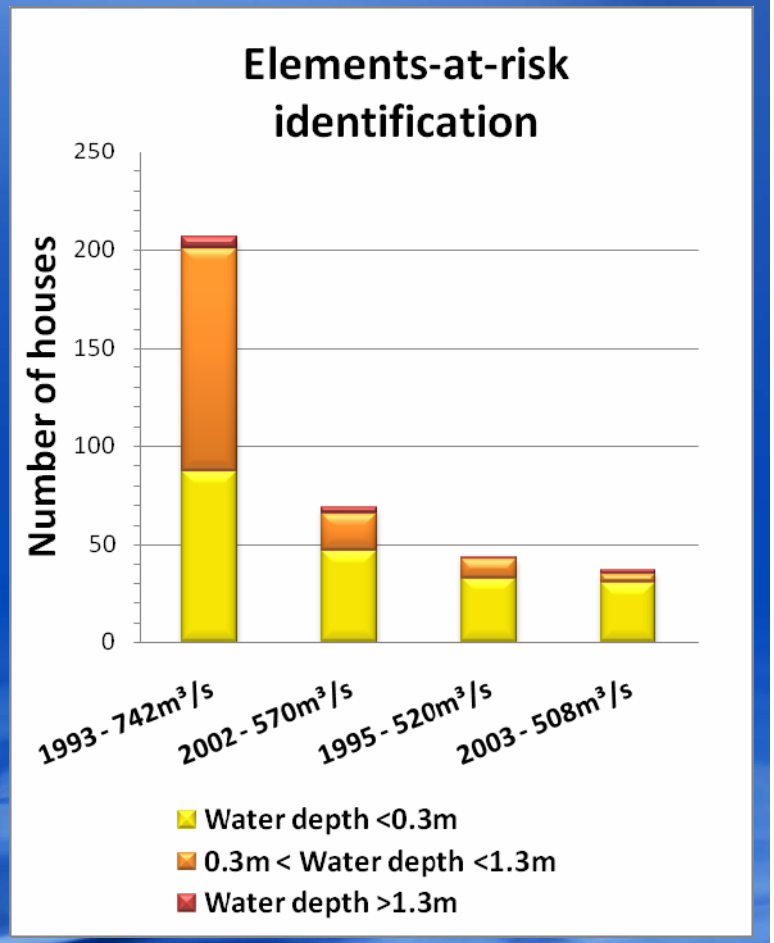


- Inundation in Rendeux (River Ourthe)
- Flood of February 2002
- Discharge : 165m^3s^{-1}

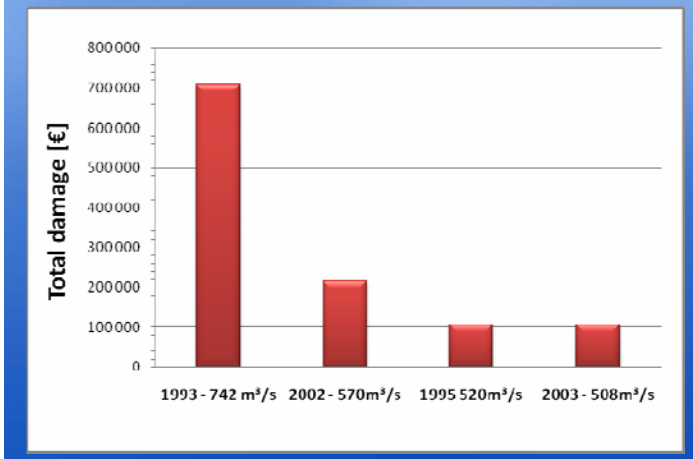
• Applicability : elements-at-risk identification

- Combination of inundation extent and land use maps
- Selection if at least one mesh is wet in the vicinity of the assets
- 3 classes of water depth
  - < 0.3 meter
  - > 0.3 and < 1.3meter
  - > 1.3meter

Usually used in inundation analysis

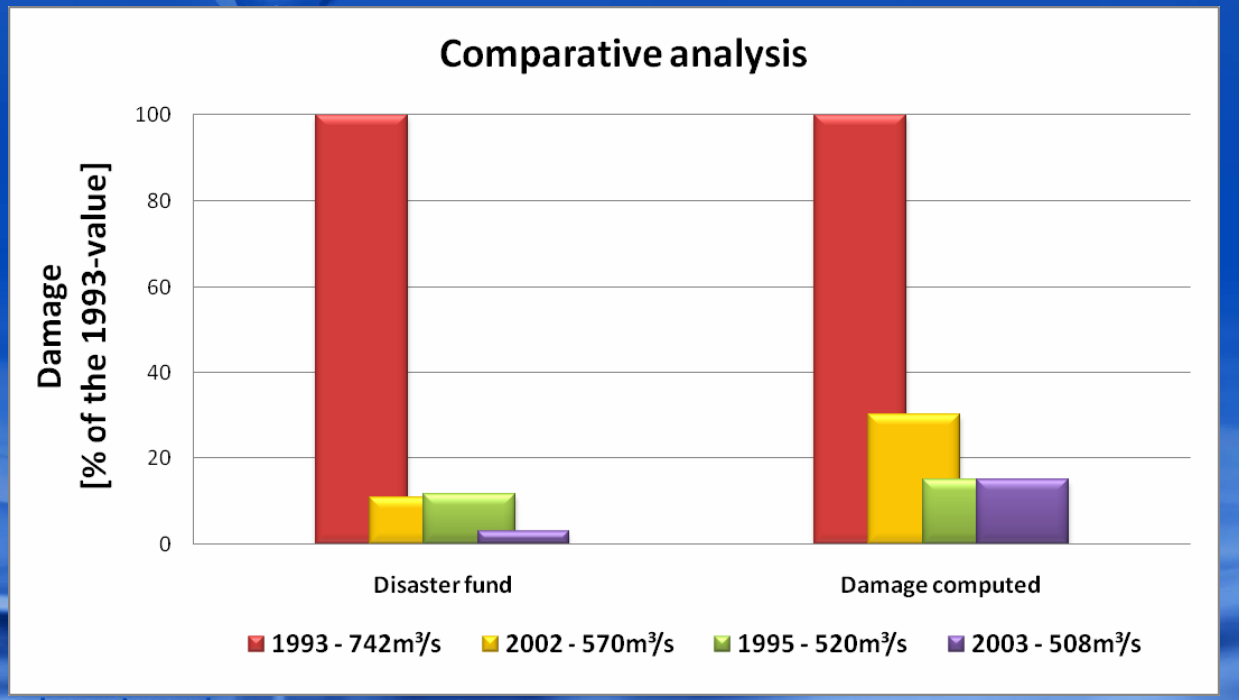


• Applicability : economic damage assessment



Economic assessment of the damage to houses
(Case study : reach 1)

Economical hypothesis :
Damage function : ICPR Rhine Atlas
Specific value : Netherlands



Comparative analysis

- Data from *Disaster fund*

⚠ all the affected houses do not get compensation

- Computed damage

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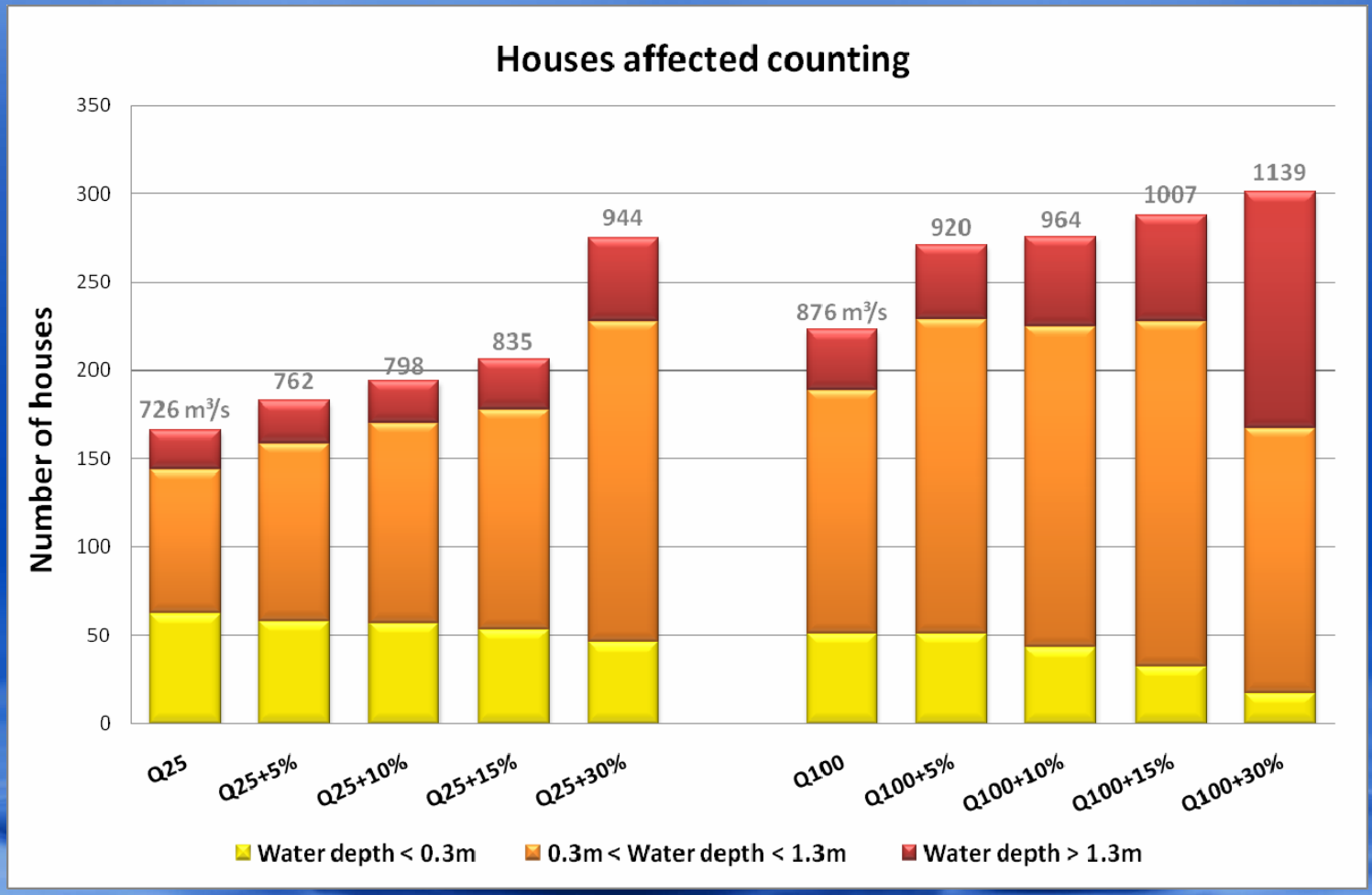
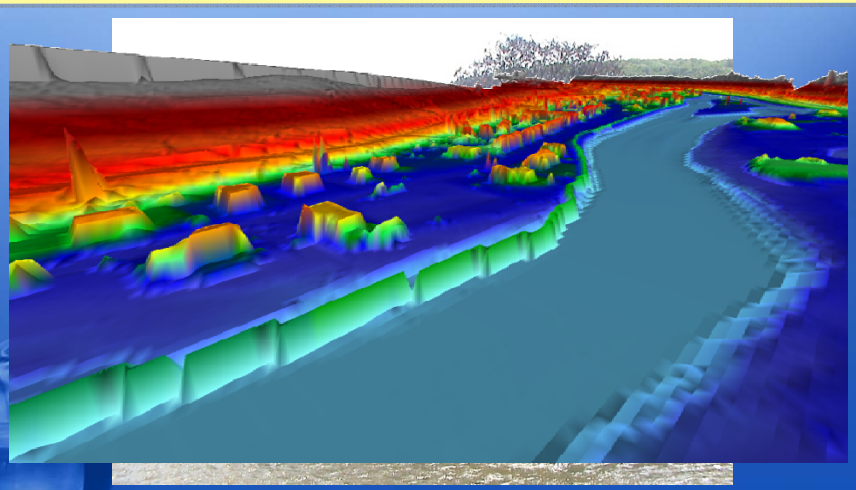
CLIMATE CHANGE ACCOUNT

- Climate change scenarios
  - Perturbation factors affecting the flood peak discharges
  - Discharge assumptions will be confirmed / improved by hydrologic models

- Houses counting for each scenario (3 classes of water depth)



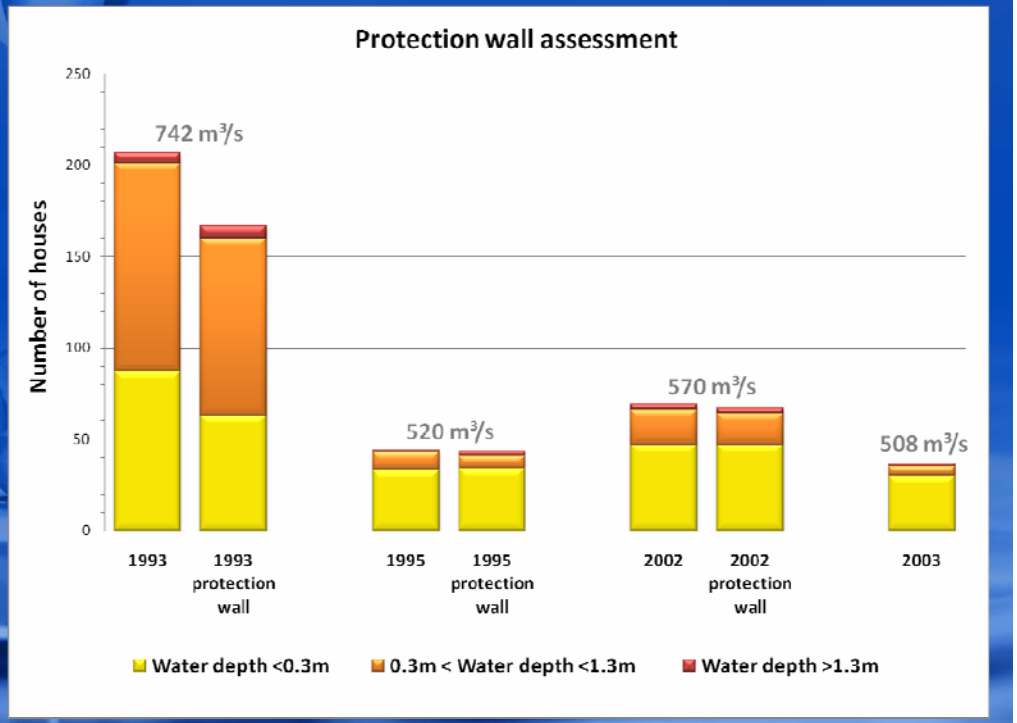


• Mitigation measures evaluation

Comparison of real configuration and with protection wall

Real configurations

1993 - 742m³/s	• No protection wall
1995 - 520m³/s	• No protection wall
2002 - 570m³/s	• Partial protection wall
2003 - 508m³/s	• Protection wall



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CONCLUSIONS

- Conclusions
  - Geomatics tools and data devoted to a micro scale analysis with very limited field survey
  - The high resolution geographic data leads to very detailed investigation
    - Validated hydrodynamics results - *Hydraulic*
    - Applicability demonstration in the context of climate change - *Economic*
- Perspectives
  - Validating and refining the overall procedure
  - Quantifying uncertainties
  - Embedding in a Decision Support System dedicated to the selection of most cost effective flood protection measure

Thank you for your attention

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