Brno University of Technology
Faculty of Civil Engineering

Department of Water Structures

Risk analysis methodology
Semi-quantitative methods

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Contents

- I. Risk Matrix
- II . FMECA

I. Risk Matrix – basic concept

Flood scenarios Sc_i – N-year floods with probability P_i

Definition of flood intensity $IP_i(v, h)$

- **Expresses flood hazard, destructive effects**
- **Represents flood losses**

Risk RI_i expressed by zones (colours), two methods

- **Risk matrix**
- **Partial risk $RI_i = IP_i \times P_i$, total risk – maximum or sum ???**

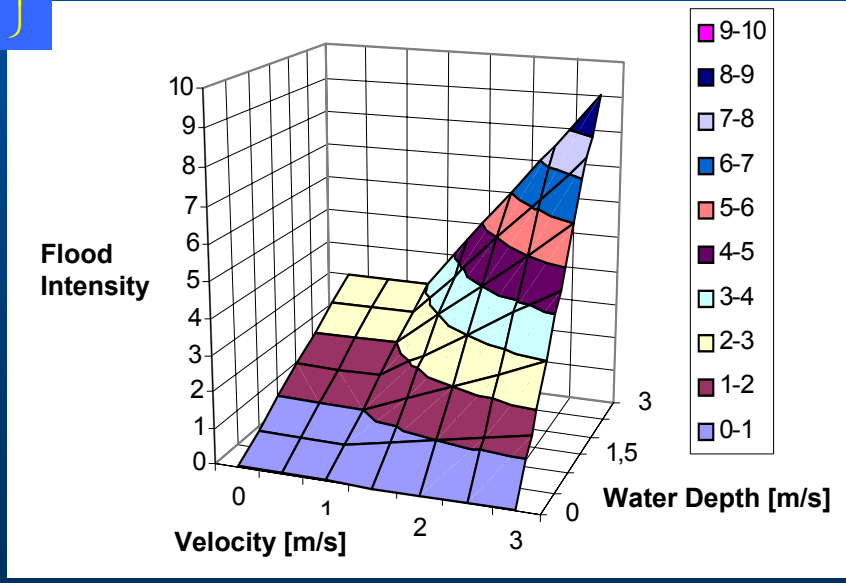
Zones – limits for behaviour (urbanisation, activities,…)

I. Risk Matrix – flood scenarios

- **Flood scenarios**
  - **According the Czech legislation N = 5, 20, 100**
  - **CHMI – provides**
    - **Standard data … N = 1, 2, 5, 10, 20, 50, 100,**
    - **Non-standard data (hydrological study) N > 100**
- **More scenarios – more computation effort**
- **??? How the number of scenarios affects resulting *RI* ???**

I. Risk Matrix – flood intensity

- **Flood Intensity - two methods**
  - ***IP = v.h***
  - $$IP = \begin{cases} 0 & h = 0 \\ 0{,}3 + 1{,}35.h & h > 0,\ v < 1\ m/s \\ 0{,}3 + 1{,}35.h.v & v > 1\ m/s \end{cases},$$



I. Risk Matrix – probability

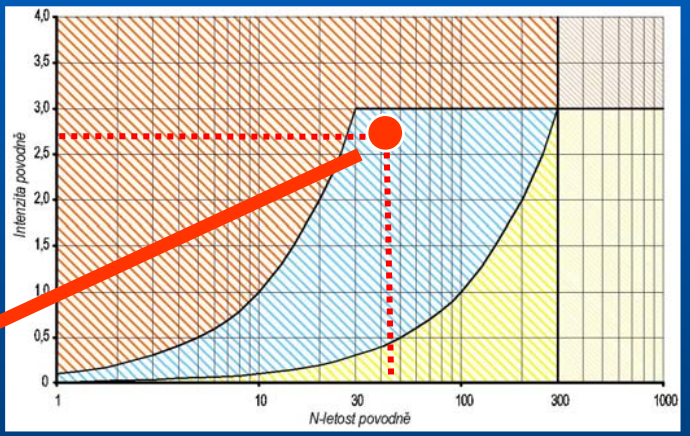
-probability :

$$P = 1 - e^{-\frac{T}{N}} \qquad T = 1\,year \qquad P \approx \frac{1}{N}$$

I. Risk Matrix – partial risk

Partial risk for i^{th} flood scenario SC_i

$$RI_i = IP_i \,.\, P_i$$

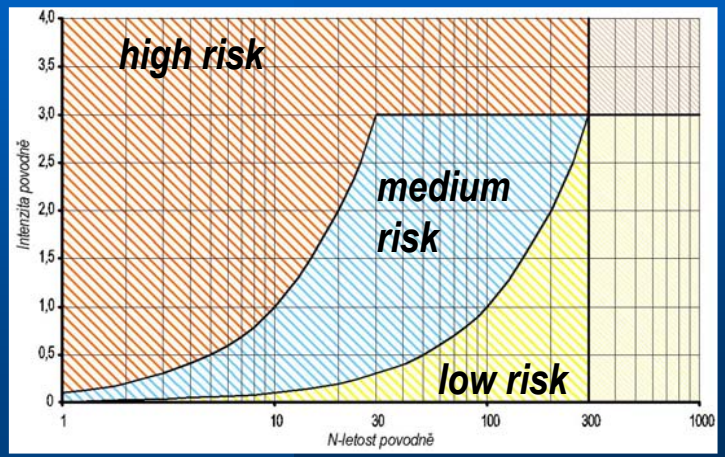


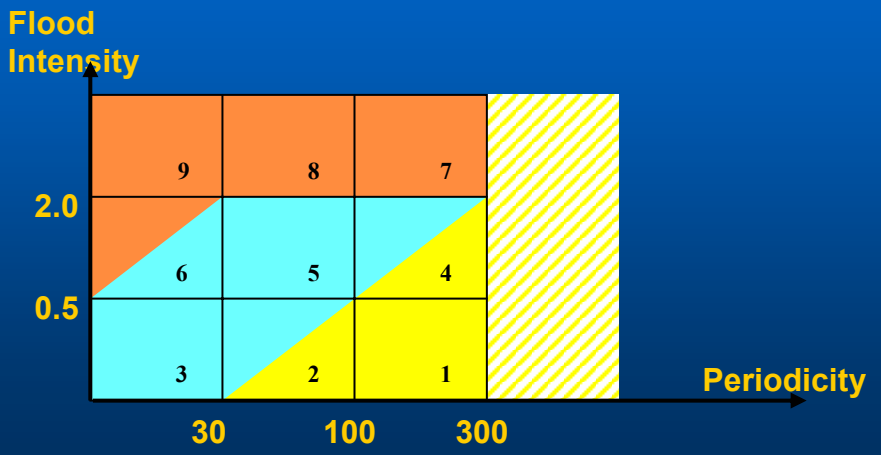
RISK *RI*	RESTRICTIONS
RI < 0,01	Measures required for sensitive structures (hospitals, ...)
0,01 < RI < 0,1	Construction possible under restrictions
RI > 0,1 or IP > 3	No residential buildings permitted

I. Risk Matrix – quantification

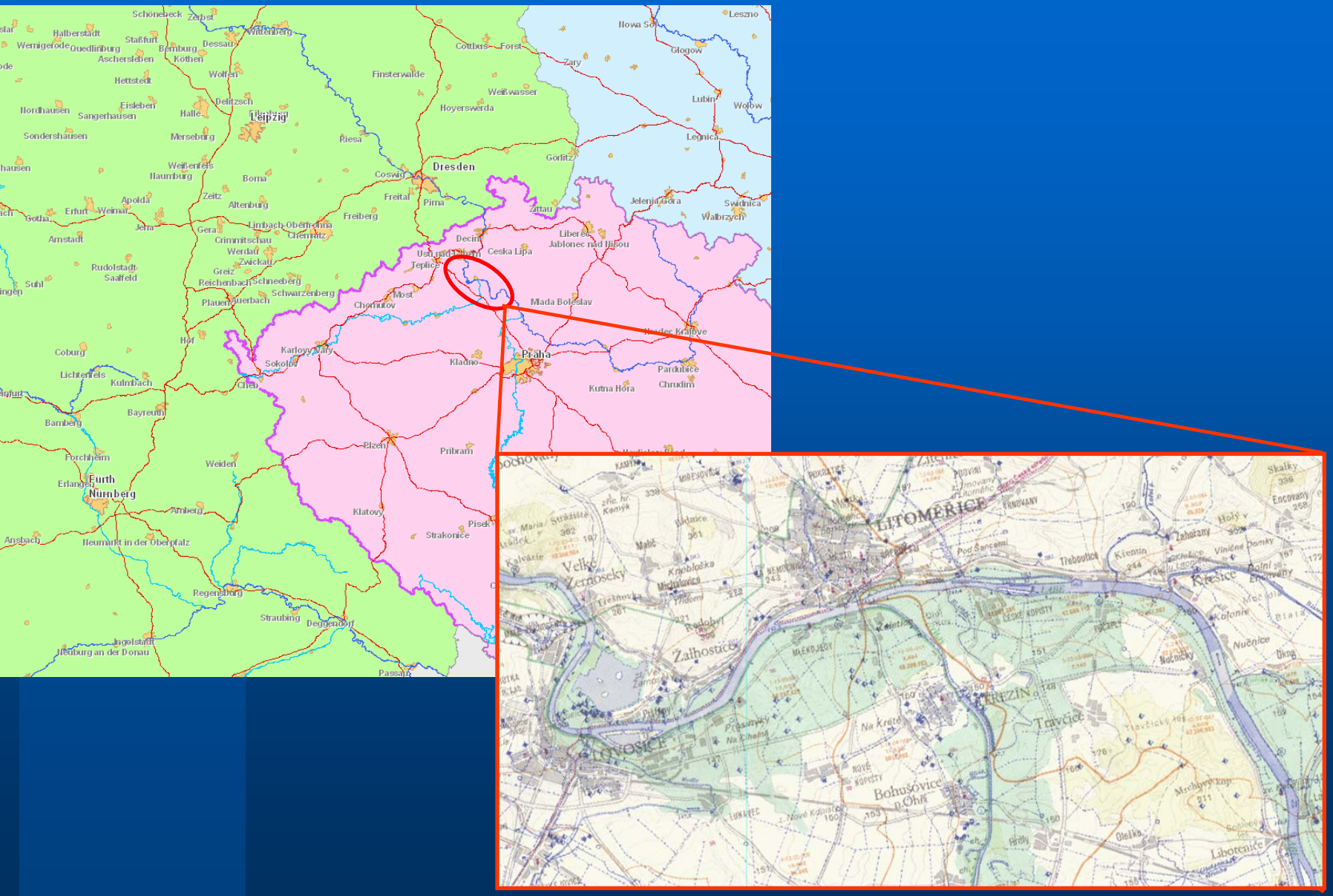
- **partial risk:** $RI_i = IP_i \cdot P_i$

- **total risk**
  - **maximum** $RI_{max} = \max_{i=1}^{n} RI_i$
  - **average** $RI_{norm} = \frac{1}{n} \sum_{i=1}^{n} RI_i$



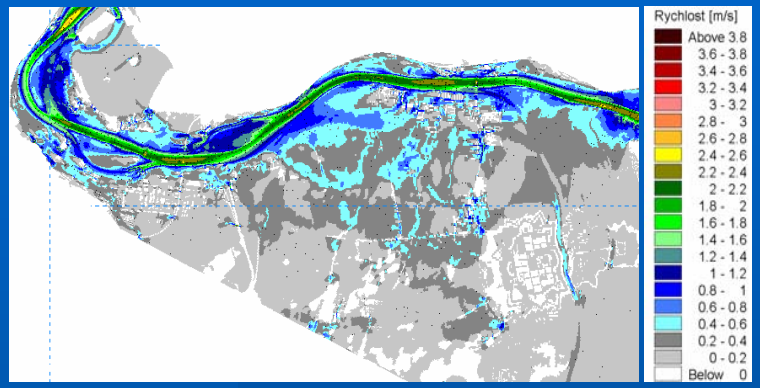


Case studies - layout

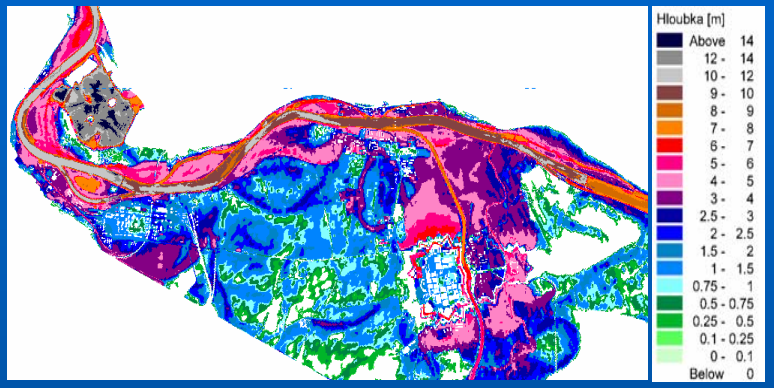


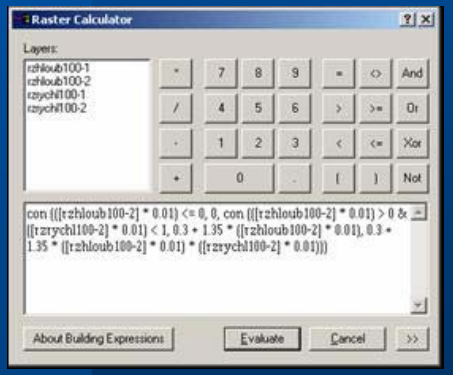
Case Study – Locality Litoměřice

Velocity [m/s] (Raster data)

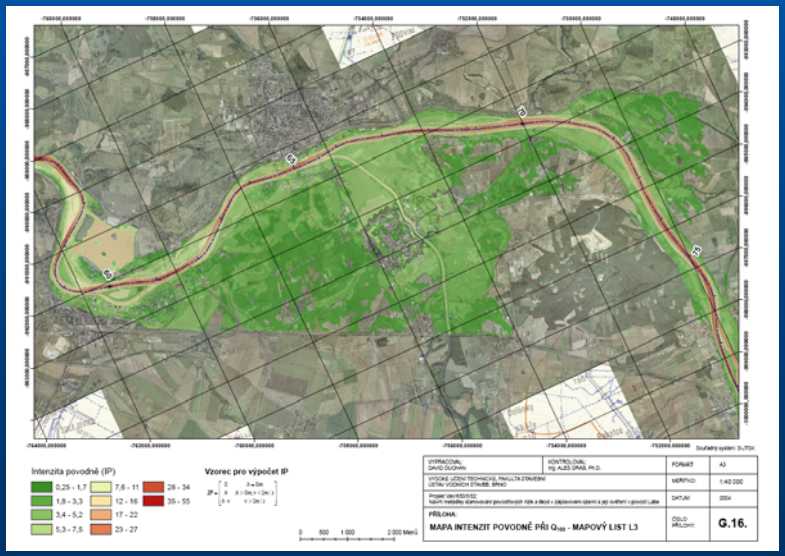


Water Depth [m] (Raster data)





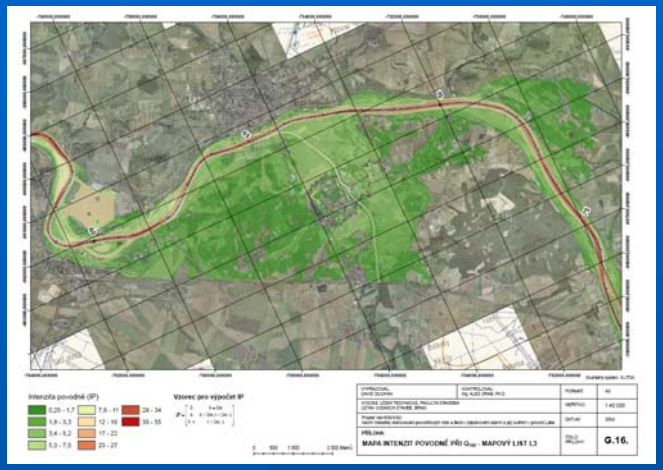
ArcGIS Raster Calculator



FLOOD INTENSITY (Flood Hazard)

Case Study – Locality Litoměřice

FLOOD INTENSITY (Flood Hazard)



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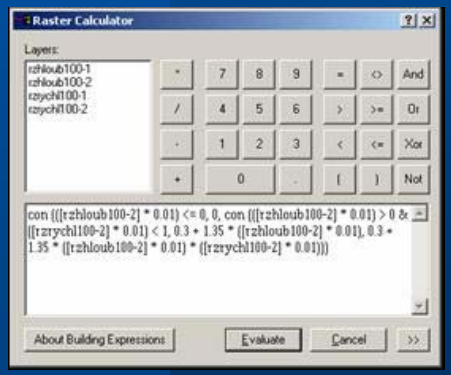
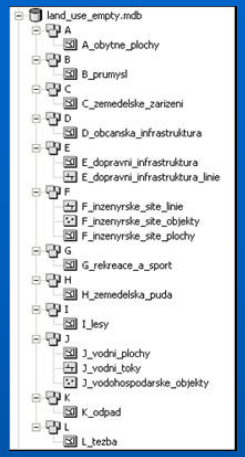
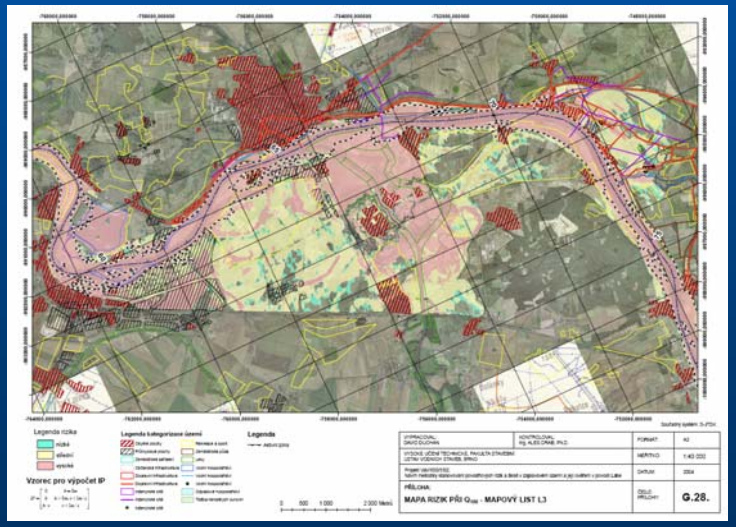


ArcGIS Raster Calculator

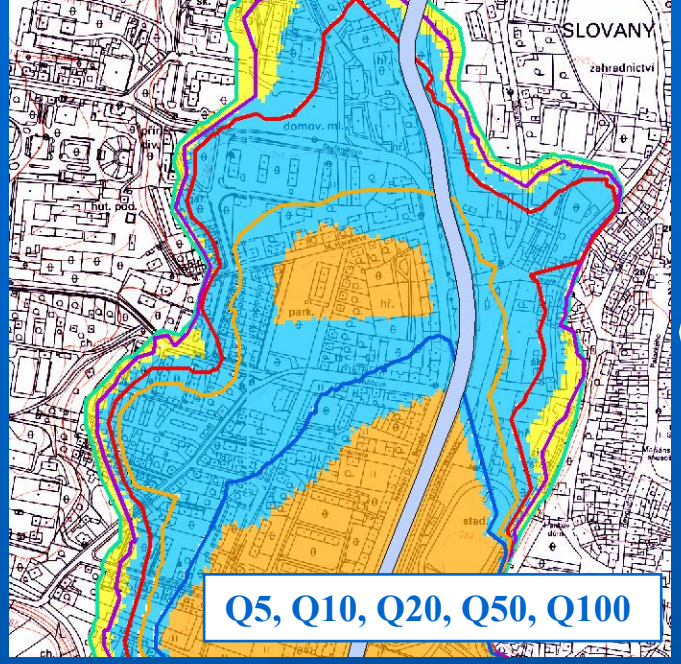
Vulnerability

Geodatabase

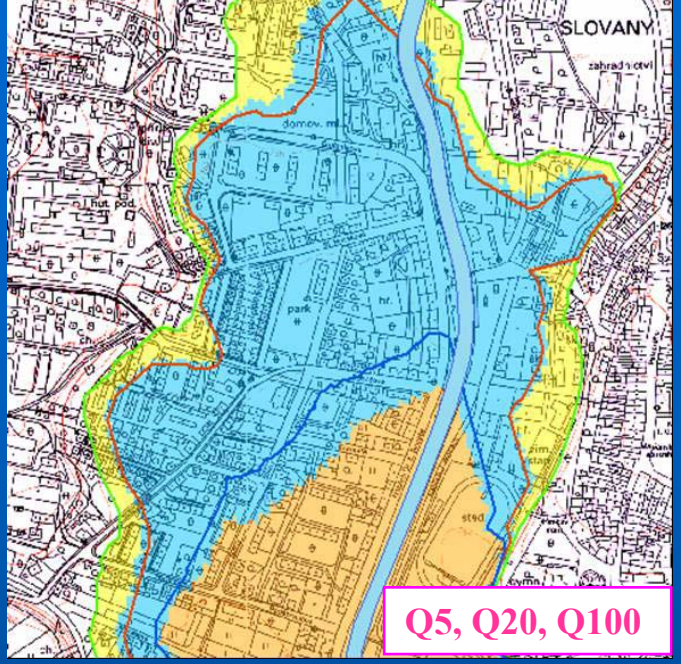


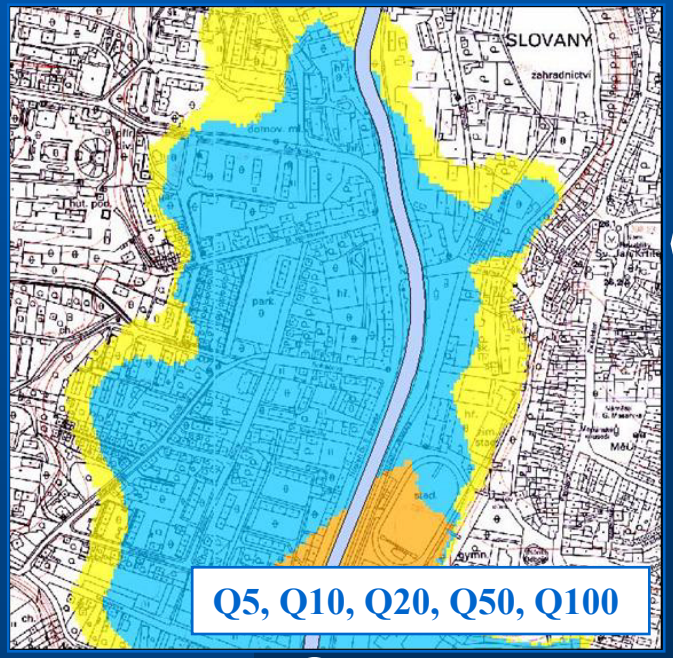


Risk and Vulnerability Map



$$RI = \max_{i=1}^{n} RI_i$$





$$RI = \frac{1}{n} \sum_{i=1}^{n} RI_i$$

Case Study – Locality Dvůr Králové

RISK MATRIX

Partial conclusions – risk matrix

specifying hazardous areas

alternative to „active zones“ approach (CZ standard)

suitable for urban planning

recommendations:

- **maximum risk (hazard) approach**
- **as much as possible flood scenarios**

Failure modes, effects and criticality analys (FMECA)

- Scaled factors
  - Probability *BP*
  - Consequences *BC*
- Risk definition
  - classical approach

$$RI_i = \sum_{i=1}^{n} (BP_i + BC_i) \quad i = 1 \ldots n$$

  - improved

$$RI = \sum_{i=1}^{n} \sum_{j=1}^{4} \sum_{k=A}^{N_{RU}} BP_{i,j,k} \cdot BC_{i,j,k} \cdot F_{i,k} \cdot w_{j,k}$$

FMECA – probability ranking

Probability	Scale factor
Not probable, no experiences, repeatance less than 1000 years.	1
Low probability, historically partial experiences, repeatance less than 100 years.	2
Medium probability, occasional occurrence, frequency from 20 to 50 years.	3
High probability, well known consequences, repeatance once in 5 to 10 years.	4
Expected, almost certain with repeatance higher than 2 years.	5

FMECA – consequences ranking

onsequences	Scale	Material losses	Social impacts	Environmental losses	Lives and health
xtreme, atastrophic	**5**	Catastrophic consequences, loss of historical monuments, long termed effects, massive evacuation, damage of infrastructure	extensive social impacts, unemployment, loss of dwelling	Ecological catastrophy international impacts, irreversible changes	Multiple casualties, injuries (from hundreds to thousands).
igh	**4**	Significant damage of infrastructure, remediation from national sources (bill. EUR), evacuation.	higher impacts, individual economical collapses and unemployment	Vast losses, hardly renewable national extent, contamination.	Individual casualties, extensive health problems .
edium	**3**	medium losses, remediation from regional resources, (several mill. EUR).	Local cons. at the most vulnerable individuals	Local damages of species, reversible	Mortality not probable, medium heal problems.
ow	**2**	Low losses, remediation from local sources	Low consequences	Minor damage on species	Not dangerou injuries
egligible	**1**	Negligible losses	No consequences	Practically no consequences	Minor indiv.l injuries

II. FMEA -> FMECA

- **FMEA – Consequences Cards – for each category of landuse**

Category

Identification

Agregovaný reprezentant území:	Podrobnější členění:	Identifikátor:
OBYTNÉ PLOCHY VČETNĚ VYBAVENÍ	UZAVŘENÉ BLOKY	A1

Ilustrační foto:

Dopady: **Střední** Bodové hodnocení: 3

Typ škody:	Hmotné škody	Sociální dopady	Škody na životním prostředí	Škody na životech a zdraví
Popis:	- nánosy bahna, zanesení, zničení vnitřního vybavení - mírné porušení statiky - navlhnutí zdiva, plísně	- poškození majetku, osobních věcí, obydlí - dočasné stěhování v důsledku povodní - bankrot drobných živnostníků - nedořešené problémy v době po povodňových událostech	- kontaminace vody, půdy - znečištění okolí tuhým odpadem - únik plynu	- úmrtí nepravěpodobná - vážná poranění u menšího počtu obyvatel - značný počet lehce zraněných osob - krátkodobý šok - šíření paniky - přenos a šíření nemocí

Pozn. Škody na životech a zdraví jsou uváděny v případě výskytu osob - jiné následky v případě evakuace

Category

Identification

Agregovaný reprezentant území:	Podrobnější členění:	Identifikátor:
OBYTNÉ PLOCHY VČETNĚ VYBAVENÍ	HISTORICKÉ A CHRÁNĚNÉ OBJEKTY	A4

Ilustrační foto:

Dopady: **Střední** Bodové hodnocení: 3

Typ škody:	Hmotné škody	Sociální dopady	Škody na životním prostředí	Škody na životech a zdraví
Popis:	- nánosy bahna, zanesení, zničení vnitřního vybavení - vážná porušení statiky - zřícení budov - poškození, ztráta historicky významných památek - navlhnutí zdiva, plísně	- ztráty na majetku - ztráta zaměstnání - poškození ztráty národních kulturních památek, historicky cenných památek - nevyčíslitelné škody (historie)	- kontaminace vody, půdy - znečištění okolí tuhým odpadem - únik plynu	- úmrtí nepravěpodobná - vážná poranění u menšího počtu obyvatel - značný počet lehce zraněných osob - krátkodobý šok - šíření paniky - přenos a šíření nemocí

Pozn. Škody na životech a zdraví jsou uváděny v případě výskytu osob - jiné následky v případě evakuace

II. FMECA - final evaluation

- **FMECA**
  - $$RI = \sum_{i=1}^{n} \sum_{j=1}^{4} \sum_{k=A}^{N_{RU}} BP_{i,j,k} \cdot BC_{i,j,k} \cdot F_{i,k} \cdot w_{j,k}$$
  - **Locality Litoměřice**

Category	Identification	Consequences Card	Probability of occurrence				Consequences				Uncertainty	Floodplain Area [m2]	Total Area	Weight [%]				Risk [ha]			
			Damages	Life and Health of Inhabitants	Nature	Social Consequences	Damages	Life and Health of Inhabitants	Nature	Social Consequences				Damages	Life and Health of Inhabitants	Nature	Social Consequences	Damages	Life and Health of Inhabitants	Nature	Social Consequences
-	-	-	-									3 563 292	3 563 292	-	-	-	-	982	342	564	305
	A1	Card A1	2	1	2	2	4	3	3	4		100 391.58	100 391.58	85	90	15	95	68	27	9	76
	A2	Card A2												85	90	15	95				
Residential (incl. Equipment)	A3	Card A3												85	90	15	95				
	A4	Card A4												85	90	15	95				
	A5	Card A5												85	90	15	95				
	B1	Card B1	2	1	2	2	4	3	3	4		207 776.42	207 776.42	95	70	15	55	158	44	19	91
Industry	B2	Card B2												95	70	15	55				
	B3	Card B3												95	70	15	55				
	C1	karta C1	2	1	2	2	3	2	2	3		15 630.75	15 630.75	55	40	30	10	5	1	2	1

II. FMECA – possibilities

- **Relative risk assessment at 3 levels**
  - Level „1“ – partial risk for given flood scenario, individual landuse representative and group of consequences
  - Level „2“ – partial risk for
    - given flood scenario and individual landuse representative over all consequence classes
    - selected consequence over all flood scenarios and landuse representatives

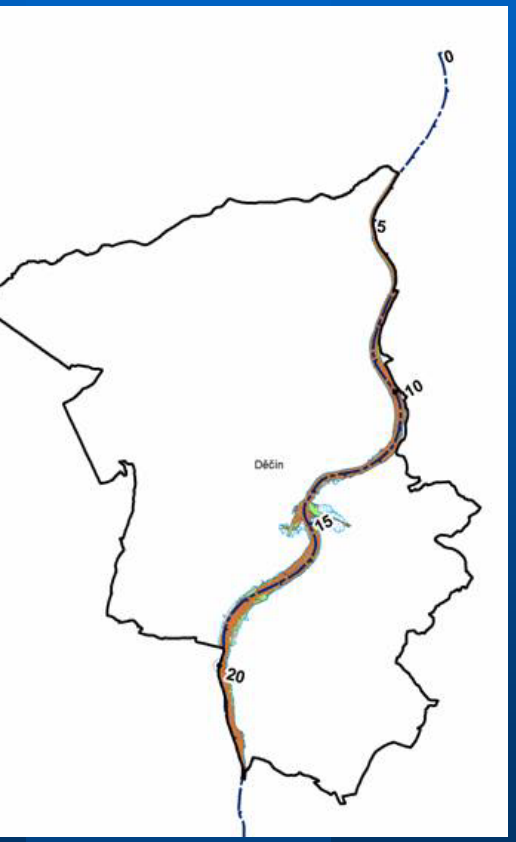
B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
			Probability of occurrence				Consequences							Weight [%]				Risk Evaluation			
Category	Identification	Consequences Card	Material losses	Life and Health of Inhabitants	Environmetal losses	Social Consequences	Material losses	Life and Health of Inhabitants	Environmetal losses	Social Consequences	Uncertainty	Floodplain Area	Total Area	Material losses	Life and Health of Inhabitants	Environmetal losses	Social Consequences	Material losses	Life and Health of Inhabitants	Environmetal losses	Social Consequences
-	-	-	-									3 563 292	3 563 292	-	-	-	-	982	342	564	305
	A1	*Card A1*	2	1	2	2	4	3	3	4		100 391.58	100 391.58	85	90	15	95	68	27	9	76
	A2	*Card A2*												85	90	15	95				
Residential (incl. Equipment)	A3	*Card A3*												85	90	15	95				
	A4	*Card A4*												85	90	15	95				
	A5	*Card A5*												85	90	15	95				

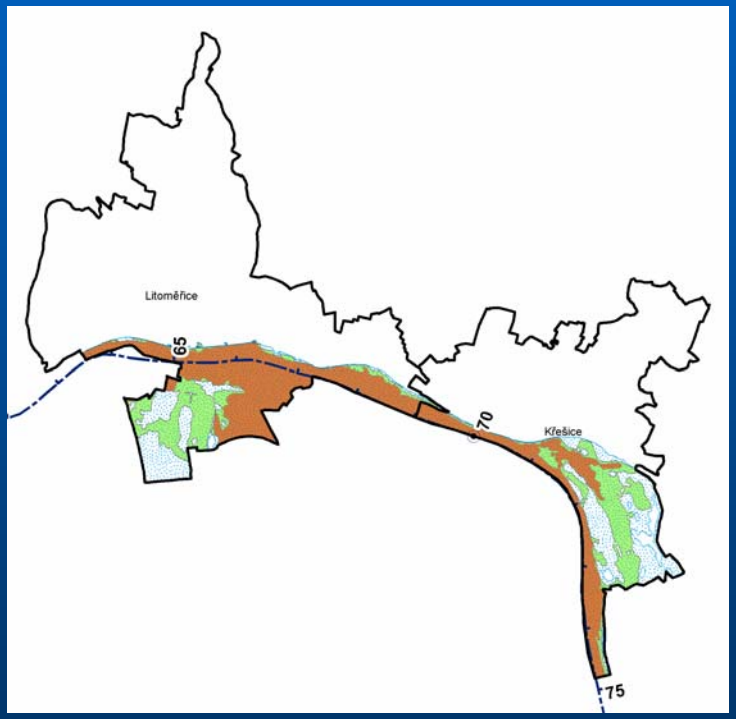
II. FMECA – possibilities

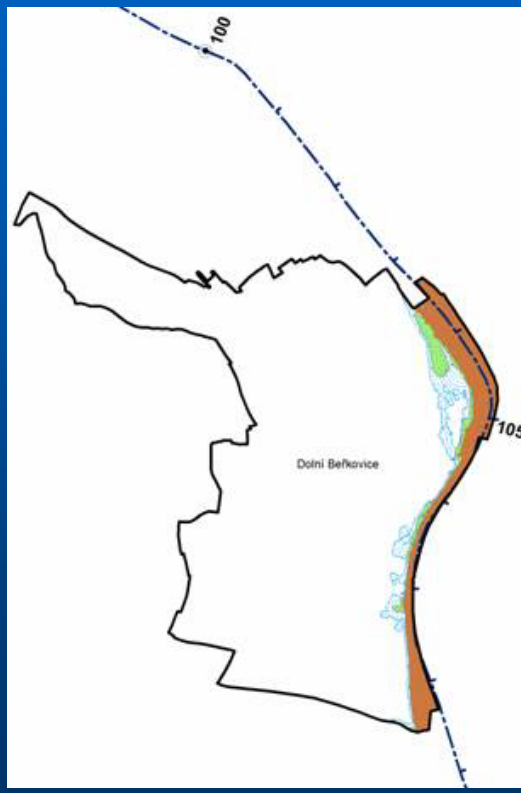
- **The method enables comparison of risks:**
  - **due to single *flood scenarios*;**
  - **for the same landuse representatives for various *flood scenarios*;**
  - **for the same groups of *consequences* for variety of flood scenarios and landuse representatives;**
  - **... ;**
- **The method combines (summarizes) different consequences**

II. FMEA -> FMECA

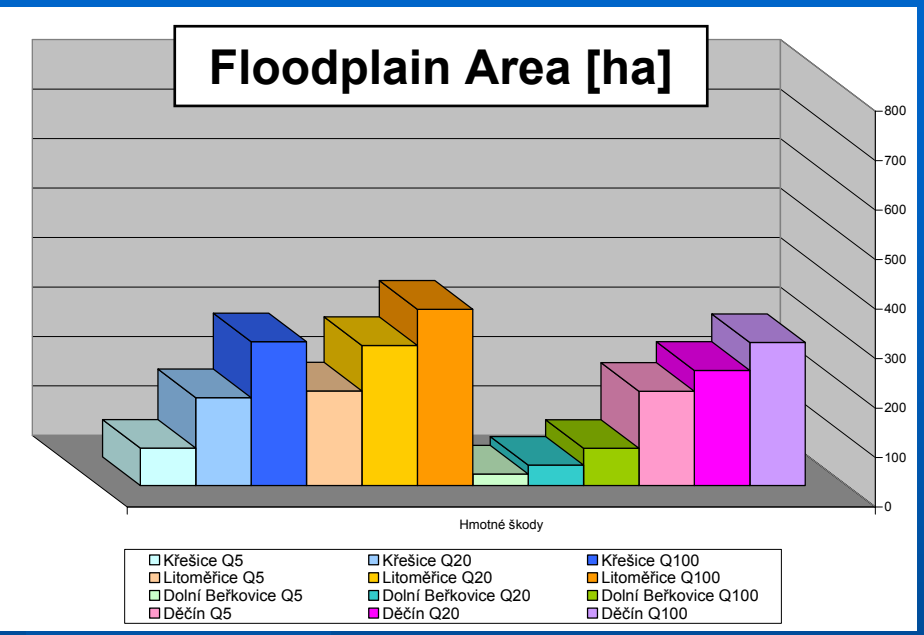
- **FMECA – Locality Děčín, Litoměřice, Křešice, Dolní Beřkovice**



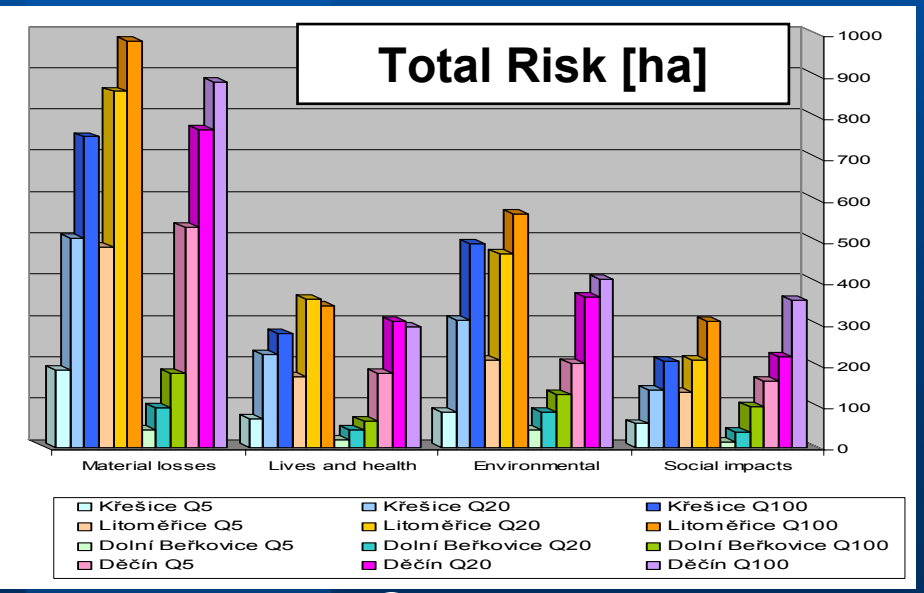


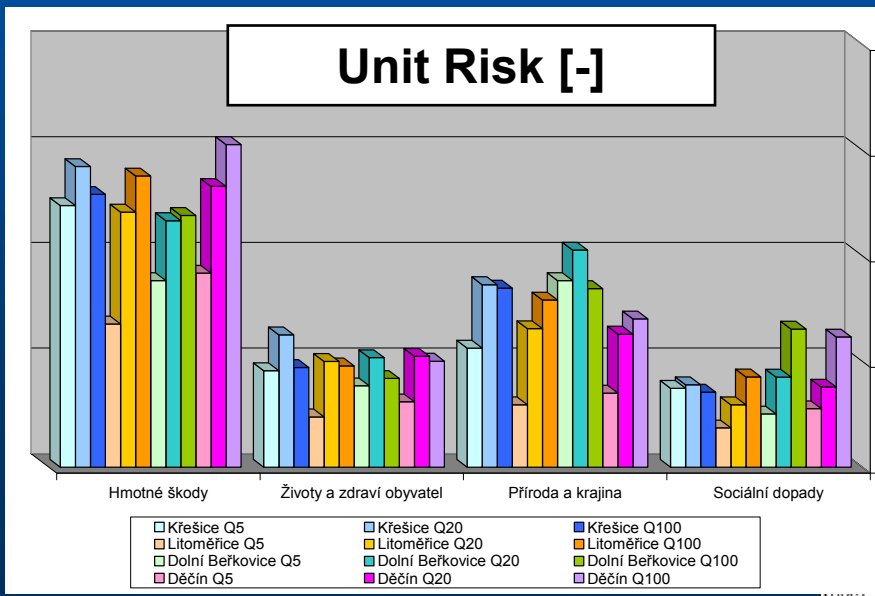


I. FMECA – comparison of risk - consequences



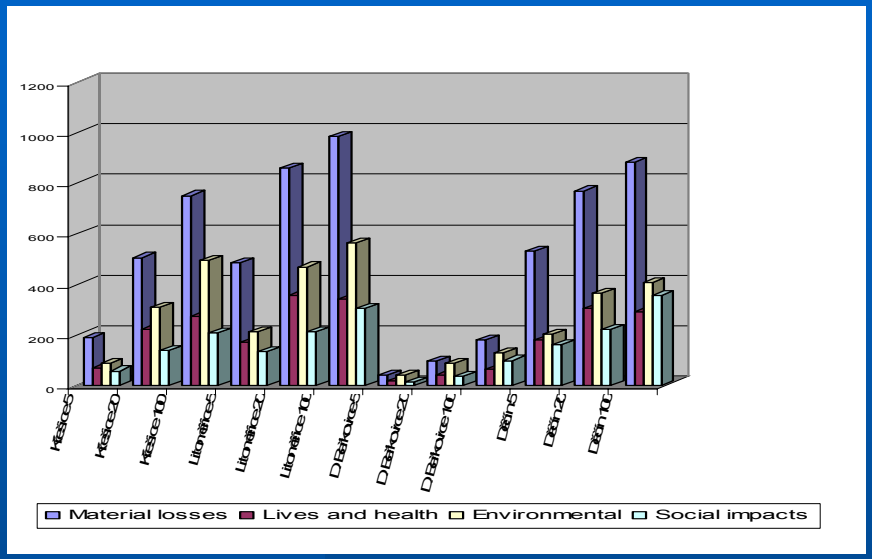
$$\textit{Unit Risk} = \frac{\textit{Total Risk}}{\textit{Entire Floodplain Area}}$$



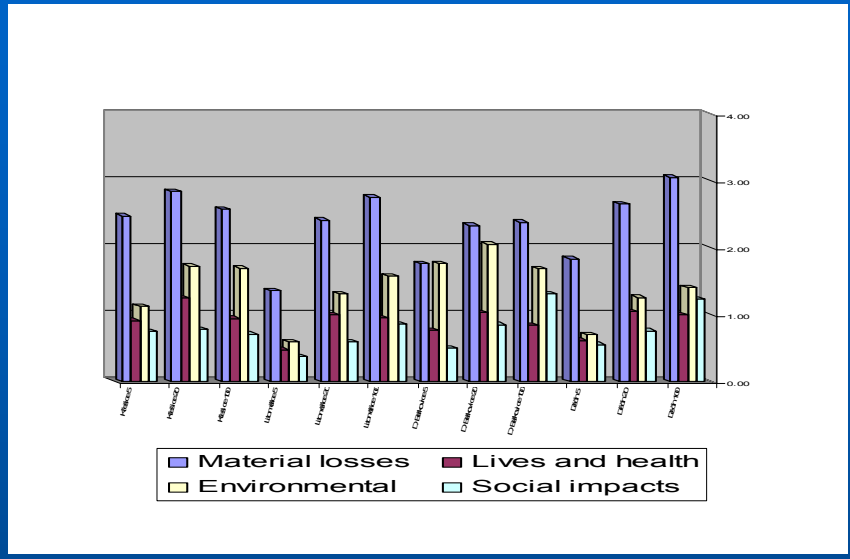


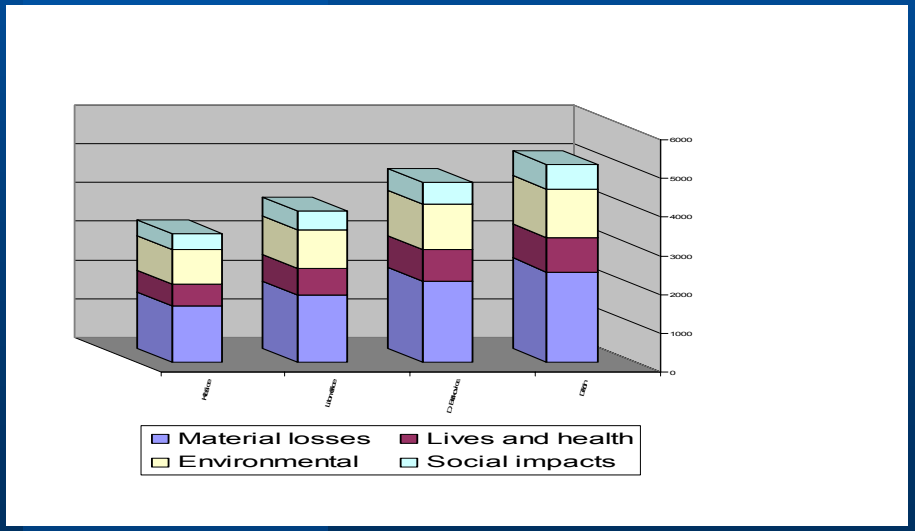
I. FMECA – comparison of risk - consequences

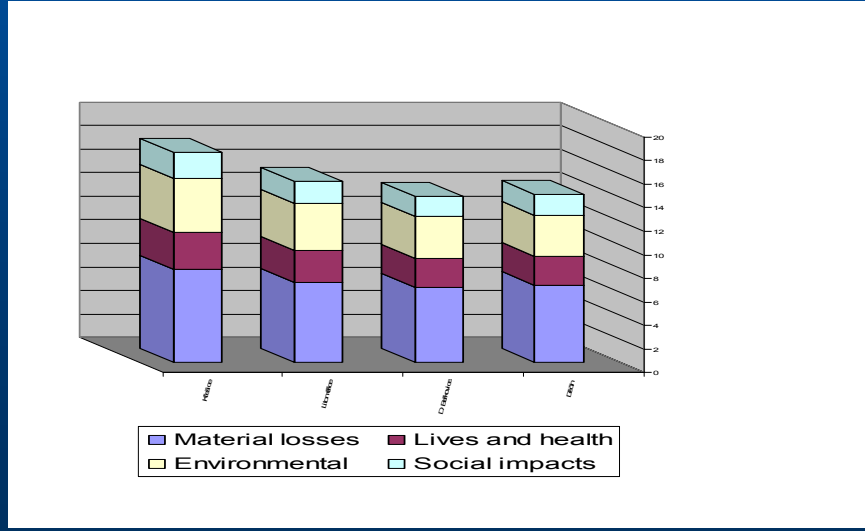
Total Risk [ha]



Unit Risk [-]







Discussion on methods used

- **Semiquantitative methods**
  - **Risk matrix**
    - Base for urban planning
    - Risk expressed spatially over the floodplain
  - **FMECA**
    - Scaled assessment of the risk
    - Partial risks
    - Integration of various consequences into one risk assessment