A methodological approach to land use-based flood damage assessment in urban areas:

Austin case study

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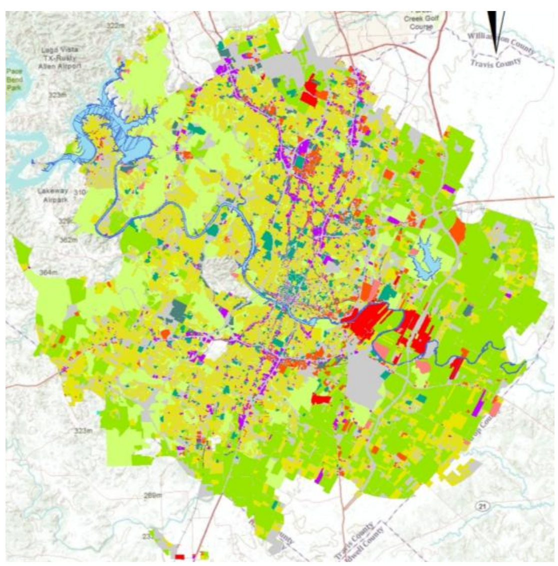
Taylor Johnson/American-Statesman

*11/15/*01: intersection of 10th and Lamar

The 1910 Great Flood in Paris

1910 – Quai de Grenelle



Land use of City of Austin in 2008

2010 **CE394K – GIS in water resources**

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Executive summary

My goal for this project is to conduct a flood loss study in the city of Austin. The purpose of this study is multiple. It could be used by insurance company for insurance rate, by people who want to take the risk to buy a house near the river or in a flood zone. It could also be companies which want to install a factory, commercial… or just government which planed the construction of flood protection equipments (dam…).

I decided to focus on a 2% Flood event because data are easily available. It is also flood event that can occur and that cost a lot of money. During, this study, I had to make some choice and some assumptions that are explained. The validity of this assumption will be discussed but this study is the first step toward a more accurate study. My argument is that I wanted to explore the different ways to evaluate flood losses more than to obtain a precise (or not) figure in dollars.

To finish, I will briefly introduce the French flood management system and the different actor of this system.

1. Introduction

1.1. Overview of flood

Floods are one of the most common hazards in the USA. Floods effects can be local, impacting a neighborhood or community, or very large affecting entire river basins and multiple states.

However, all floods are not alike. Some floods develop slowly, sometimes over a period of days. But flash floods can develop quickly, sometimes in just a few minutes and without any visible signs of rain. Flash floods often have a dangerous wall of roaring water that carries rocks, mud, and other debris and can sweep away most things in its path. Overland flooding occurs outside a defined river or stream, such as when a levee is breached, but still can be destructive. Flooding can also occur when a dam breaks, producing effects similar to flash floods.

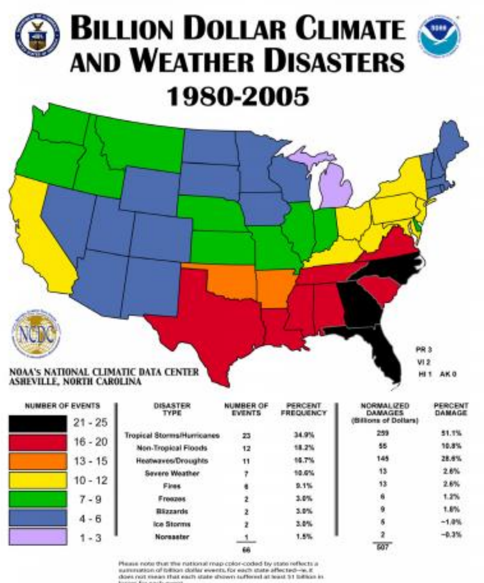


Figure 2. National Map Showing Spatial Distribution of Events by State.

Central Texas, often called "Flash Flood Alley" has been identified as the most flash-flood prone area in the USA by National Weather Service and holds 6 of 12 world record rainfall rates in 24 hours or less according to the United States Geological Survey (USGS). Some 20 million of Texas 171 million acres are flood prone (Blue Ribbon Committee Study) and about 8 millions structures are located in flood plains.

Be aware of flood hazards no matter where you live, but especially if you live in a low-lying area, near water or downstream from a dam. Even very small streams, gullies, creeks, culverts, dry streambeds, or low-lying ground that appears harmless in dry weather can flood.

Floods have also an economic impact and the total economic losses can reach some astronomical amount.

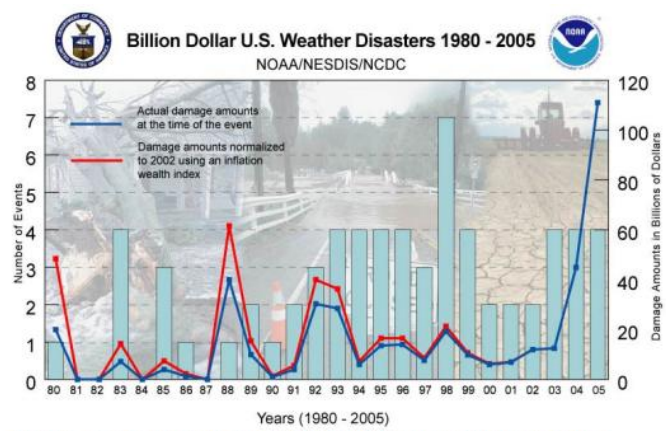


Figure 1. Time Series Graph Showing Number of Events and Dollar Costs by Year.

1.2. Historical Flooding

<u>October 17, 1998</u>.

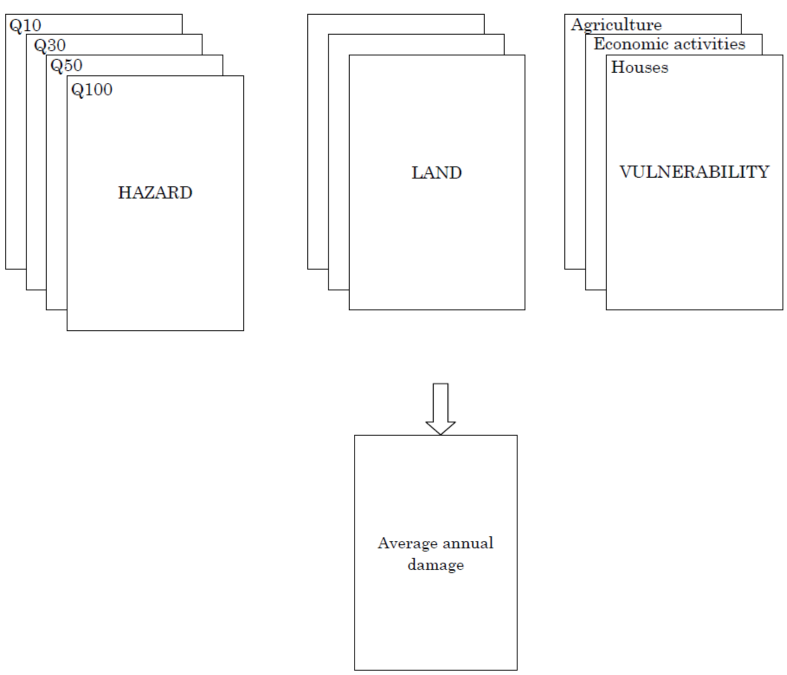
In Austin, 454 homes were damaged, with most of the damages incurred to houses along Onion Creek, Walnut Creek, and Williamson Creek. Statewide, this storm caused property damages and losses of almost $1 billion[1].

<u>May 24, 1981</u>.

This storm event will always be remembered as the "Memorial Day Flood"[2] which drowned 13 people and caused $36 million in damages. This short duration storm with intense rainfall hit many of Austin's urban creeks: Shoal, Walnut, Little Walnut, Bee, and Waller. Shoal Creek normally flows at 90 gallons per minute, but peaked during this flood at 6 million gallons per minute! Some areas received over 10" of rain in four hours.

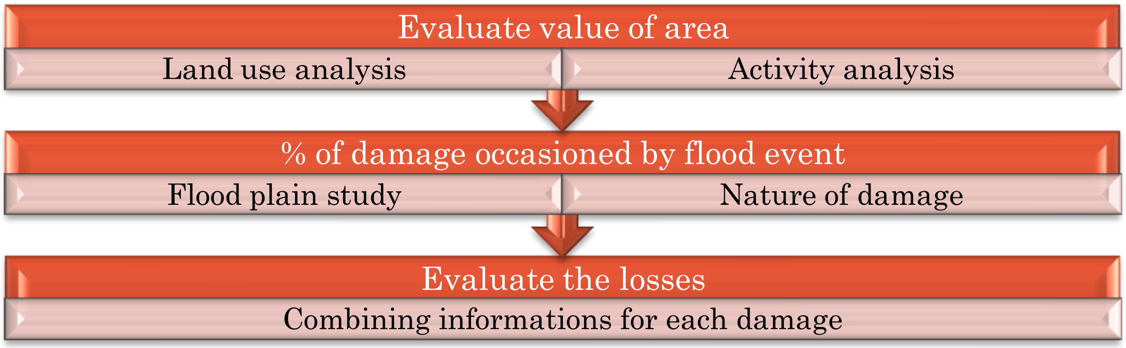
1.3. Methodology

FIGURE 1 COMPUTATION OF THE AVERAGE ANNUAL DAMAGE



The methodology used is this report is the land use approach because we are working essentially on an urban area. Crossing this information with hazard and values data, we should be able to define an average annual damage on this area as shown on figure 1.

[1] http://www.ci.austin.tx.us/watershed/floodhistory.htm
[2] http://www.cityofaustin.org/watershed/floods/default.htm

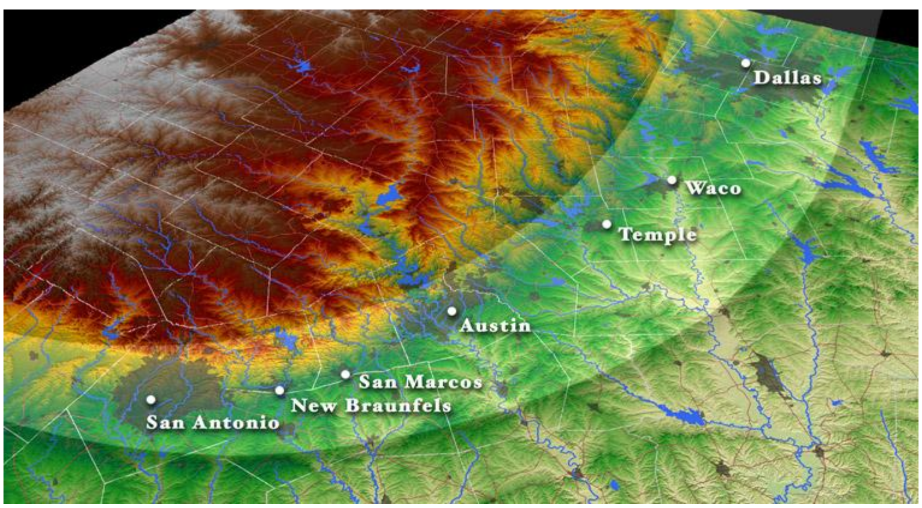


2. Study Area: Travis County – City of Austin

2.1. Localization

Austin City is located in Central Texas, in an area called the “flash flood alley” due to the strong flood events that occurred in Texas According to the National Weather Service, flash flooding is a rapid rise in water levels associated with heavy rainfall or the failure of a dam or ice jam.

FIGURE 2 FLASH FLOOD ALLEY[3]



Because the hills to the west are primarily limestone rock with a thin covering of topsoil, portions of the city are frequently subjected to flash floods from the runoff caused by thunderstorms. To help control this runoff and to generate hydroelectric power, the Lower Colorado River Authority operates a series of dams that form the Texas Highland Lakes. The lakes also provide venues for boating, swimming, and other forms of recreation within several parks on the lake shores.[4]

[3] http://www.floodsafety.com/media/maps/texas/index.htm

[4] http://www.lcra.org/

2.2. Land Use

Land use analysis is a way to classified how land is used, each type of use having its own characteristics. The land use plan brings together consideration for both the physical development as well as the social characteristics of the town.

The first step of land use analysis is to conduct an inventory of different uses. The land use inventory classified land uses into 11 major categories. The data are provided by the city of Austin.[5]

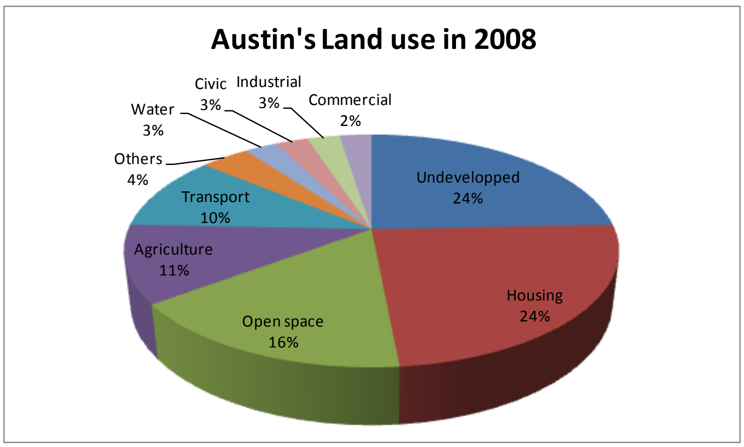
TABLE 2-1 LAND USE AND SURFACE AREA IN THE CITY OF AUSTIN IN 2008

Land use category		Total Area (km²)	% Area
Housing		**386.9**	**24.13%**
	Single Family	259.2	16.17%
	Mobile Home	28.4	1.77%
	Duplex	9.8	0.61%
	Large lot single family	48.1	3.00%
	Apartment	38.3	2.39%
	Multi family	1.3	0.08%
	Group Quarters	0.4	0.03%
	Retirement Housing	1.3	0.08%
Commercial		**40.1**	**2.50%**
Office		**27.0**	**1.68%**
Industrial		**40.8**	**2.54%**
	Manufacturing	14.0	0.87%
	Warehousing	20.1	1.26%
	Equipment services	6.7	0.42%
Mining		**23.2**	**1.45%**
Civic		**40.8**	**2.55%**
	Semi institutional Housing	2.0	0.12%
	Hospital	0.8	0.05%
	Government	7.2	0.45%
	Educational	18.5	1.16%
	Meeting Assembly	10.3	0.64%
	Cultural services	0.2	0.01%
	Cemetery	1.9	0.12%
Open space		**261.8**	**16.33%**
	Parks, Open space	80.3	5.01%
	Golf course	11.9	0.74%
	Campgrounds	8.4	0.52%
	Preserve	161.2	10.06%
Transport		**166.6**	**10.39%**
	Railroad facilities	0.8	0.05%
	Transportation termination	0.6	0.03%

[5] Austin Land use 2008 : GIS Data set : http://www.ci.austin.tx.us/landuse/gis.htm

	Aviation	15.9	0.99%
	parking	2.1	0.13%
	street	147.2	9.18%
Utilities		11.4	**0.71%**
Agriculture		173.2	**10.81%**
Undeveloped		390.7	**24.37%**
Water		41.0	**2.55%**
Total		1603.4	**100%**

FIGURE 3CITY OF AUSTIN LAND USE IN 2008

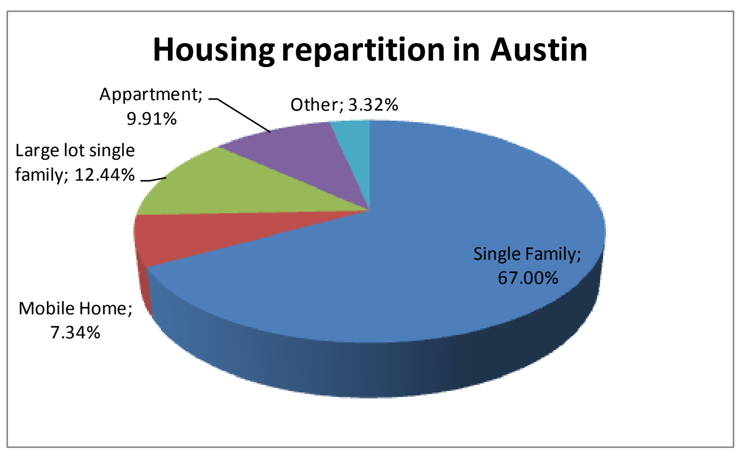


The open space+ agricultural and undeveloped areas represented more than 50% of city of Austin district. Then Housing represents 24% of areas. This is a lot and according to the spatial land use map, the main building near the river, so one of the most exposed area to flood, are houses.

Then, industrial and commercial buildings represent only 5% of the area. It is the building that could represent the biggest part of losses because of the value of inventories, and the economic activities.

The main part of buildings is housing whose repartition is shown on the chart below:

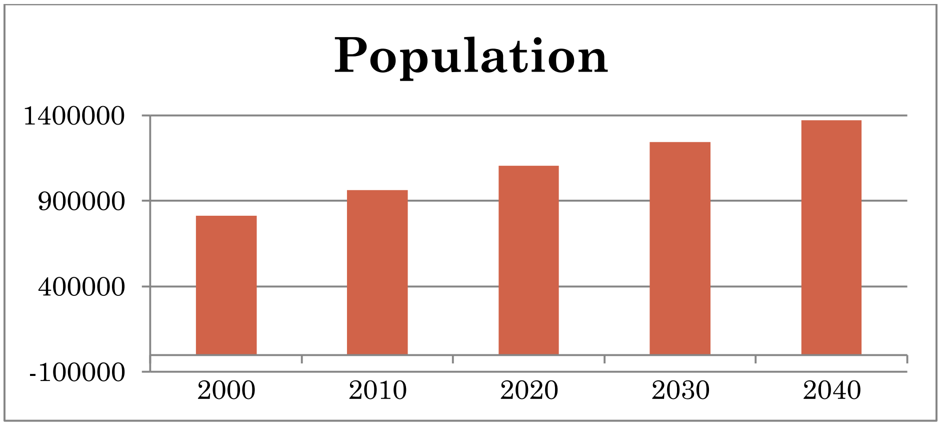
FIGURE 4 HOUSING REPARTITION OF CITY OF AUSTIN IN 2008



The inventory of property has been conducted to determine the number and type of structures, structure and content values, and ground and first floor elevations (elevation where water enters the structure). Associated with the inventory is the identification of an applicable flood depth-percent damage relationship for each structure type.

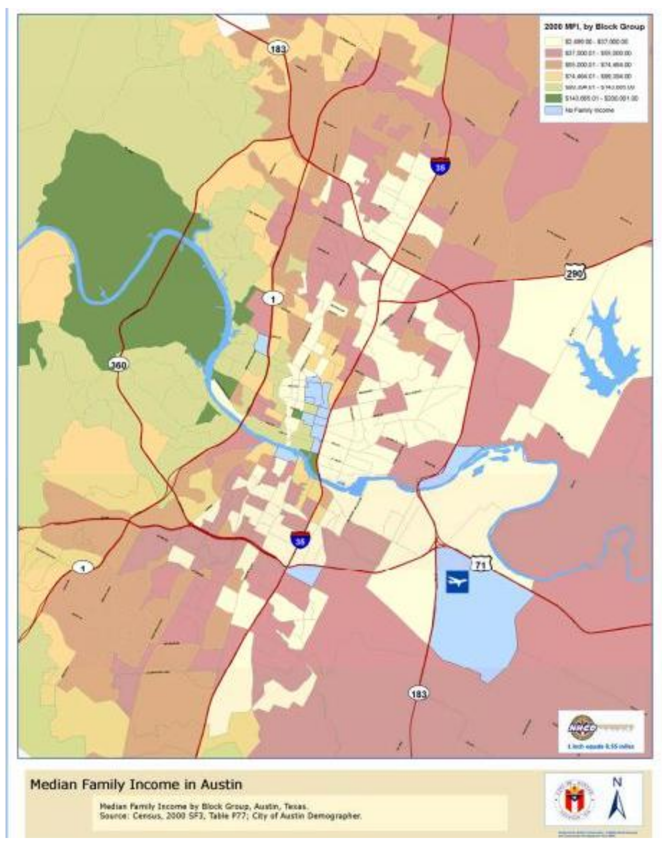
2.3. Population, Incomes

Travis County covers an area of 989 square miles, and had a 2000 population of 812,280[6], an increase of 41% over the 1990 population. By 2040, the population is expected to increase by 68%.



Per capita personal income was $35,094 and ranked 7th in the state.

FIGURE 5 PER CAPITA INCOME MAP



As expected, area with high flood risk is owned by people with lower income, whereas the most safe and most expensive area is owned by people with high incomes.

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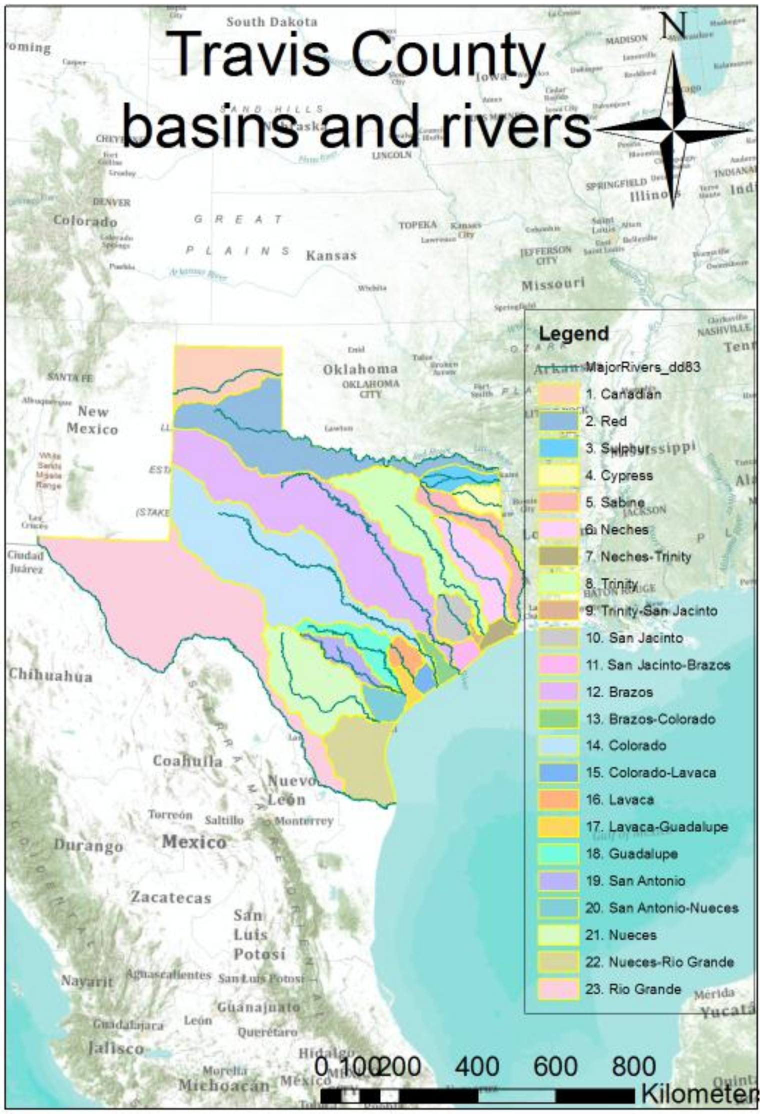
[6] Census- 2000

2.4. Hydrology

2.4.1. Basins and rivers



The city of Austin is drained by one major river, the Colorado River which is managed by the Colorado River Authority who tries to prevent flood.

2.4.2. Watershed

There are 5 watersheds in Austin dispatched into two categories: the desired development zone and the drinking water protected zone.

- Suburban watersheds
- Urban watershed

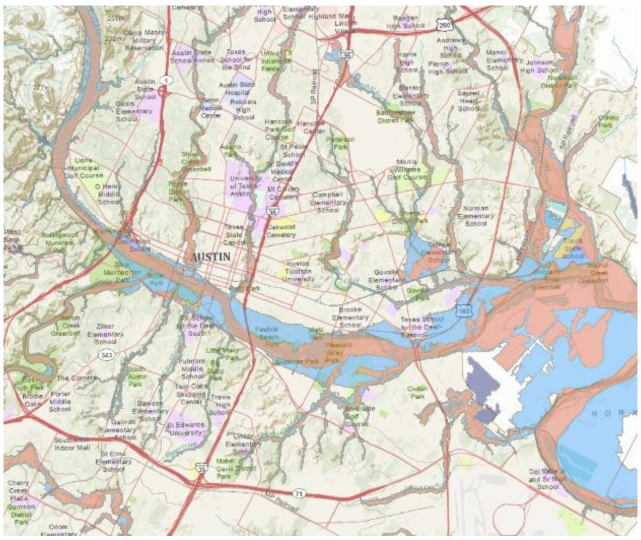
} Desired development zone

and

- Water supply suburban watersheds
- Water supply rural watersheds
- Barton Springs Zone

} Drinking protected zone

2.4.3. Floodplain



Floodplain is the most important part of this study, they give data on which part of the city are threatened by a flood event. For th 0.2PCT flood event, only 11% of city of Austin area is threatened by flood. By identification of the main area threatened, we can say that residential area (most especially single family housing) will be threatened by flood whereas industrial building will be relatively saved from the flood. Commercial building including restaurant will be also threatened but less than housing.

3. Economics

3.1. Purpose

"Damage results from the conflict between nature made flooding and human usage. The type and extent of damage continuously changes with development in society." (ICPR, 2002).

3.2. Methodology

The methodology used here is first to evaluate the value of an area and then to evaluate which percentage the flood event losses represent.

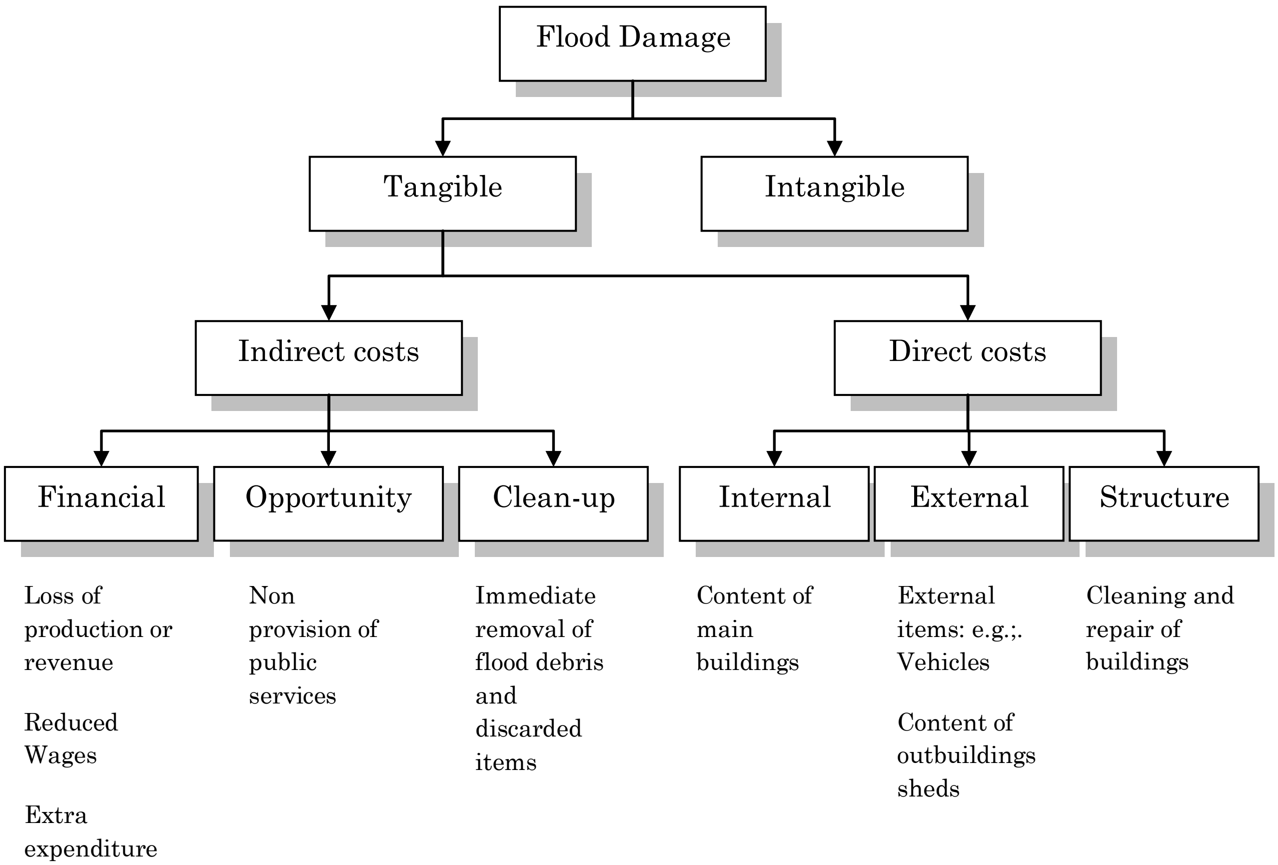
The computation of flood damages is based upon the depth of flooding for various flood events (exceedence probabilities), and a relationship between the depth of flooding and the estimated damages based upon a percentage of the structure and content, or vehicle value.

3.2.1. Natures of costs.

An important step is to define, list and categorize the different losses that can affected an area. There are different type of losses that involved human or animal life and a large variety of economic losses of tangible or intangible nature. When put together, it defines the Probable Maximum Loss.

- Direct costs are physical damages to buildings, inventories… and can be evaluate directly by the cost of same standard replacement.
- Indirect costs are flow damages such as business interruption, cleaning costs, evacuation costs.

FIGURE 6 TYPE OF FLOOD DAMAGE



A distinction should be done between tangible and intangible costs. Tangible costs can be evaluated by an amount of dollars (such as building reconstruction or replacement, inventories….) whereas intangible costs cannot be assessed by money (what is the price of a human life? Life insurance? $10M?...). In this report, only tangible costs will be considered.

3.2.2. Impact parameters

There are quantities of parameters that are involved in flood impacts assessments. The most important are:

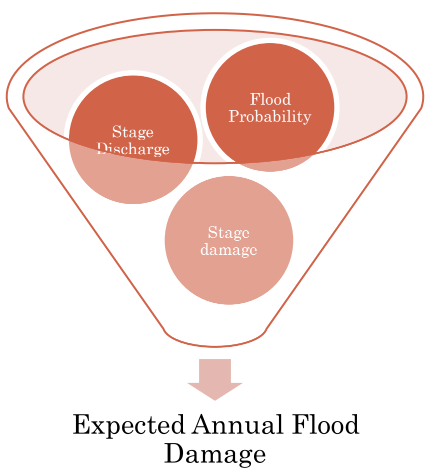
- Water height
- Velocity of flood's flow
- Duration of flood
- Rate of water rise during the flood
- Others more specific (seasonality for agriculture…)

This is resumed in the following table:

Depth	Flow duration	Rising rate
• Housing	• Housing	• Housing
• Industrial	• Industrial	• Industrial
• Commercial	• Commercial	• Commercial
• Transport		
• Open Space		

Depending of the type of building in an affected area, a model provided allows the computation of the losses (direct or indirect) using this information. This model is a damage function that

3.2.3. Expected Annual Damage



The Expected or Average Annual Damage can be computed from the land use plan and the floodplain. Knowing the land use type of an area, we can use the appropriate parameters in order to evaluate the value of this area and so to compute the direct costs of the flood event. The same process could be used to evaluate the indirect cost of the flood event.

3.3. Land use

3.3.1. Structural/Content Value

The computation of losses by flood relies on the height/depth of flooding and relationship between the depth and the expected damages on a vehicle or a structure, content… This damage is a percentage of the value of the vehicle, structure or content. Using this information, we can compute the expected damage for one year or expected annual damage (EAD).

For example, in this study, we would consider a 200-year frequency flood or 0.2% flood event. That means that this flood has one percent chance to be equaled or exceeded in any given year.[7]

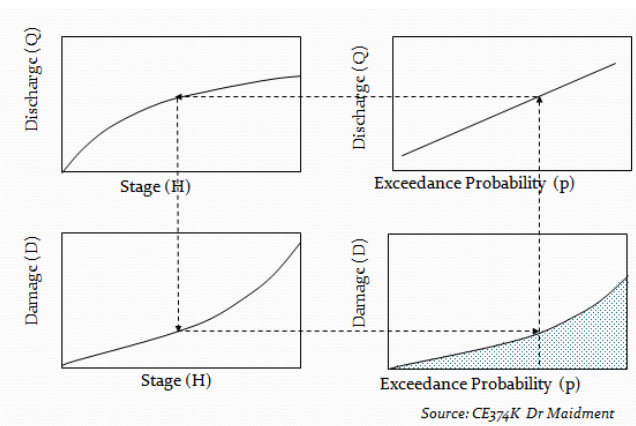
Structure values could be the current price of the structure, or the price to rebuild the structure (replacement costs) or the price to repair the structure.

The replacement costs are not representative of the reality because it doesn't take into account depreciation due to deterioration occurring before the flood event and it tends to overestimate the cost of the flood.

The reparation costs are the most useful for owners and it is that price they are looking for.

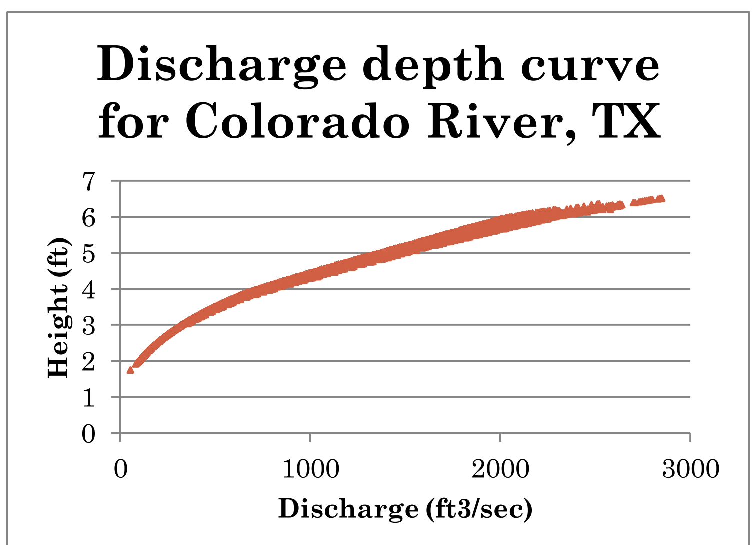
The current price could be the market price and it used by insurance companies. We can have access to these data (market price map of city of Austin, Annex 6).

3.3.2. Flood/Damage relationships



One relationship that can be used is the depth-percent damage relationship which relate the depth of flooding relative to the structure (first floor usually) and contents as a percent of the total estimated value. First, we need to know the height of flood, which can be computed following the next schema. We first need to know the exceedence probability to have the discharge of the stream and then using USGS data, we can compute the height of flood that we were looking for.

Discharge depth curves can me made using USGS gauge data. For example, using USGS 08158000 Colorado Rv at Austin, TX [8] data, we can plot the following discharge-depth curve for Colorado River

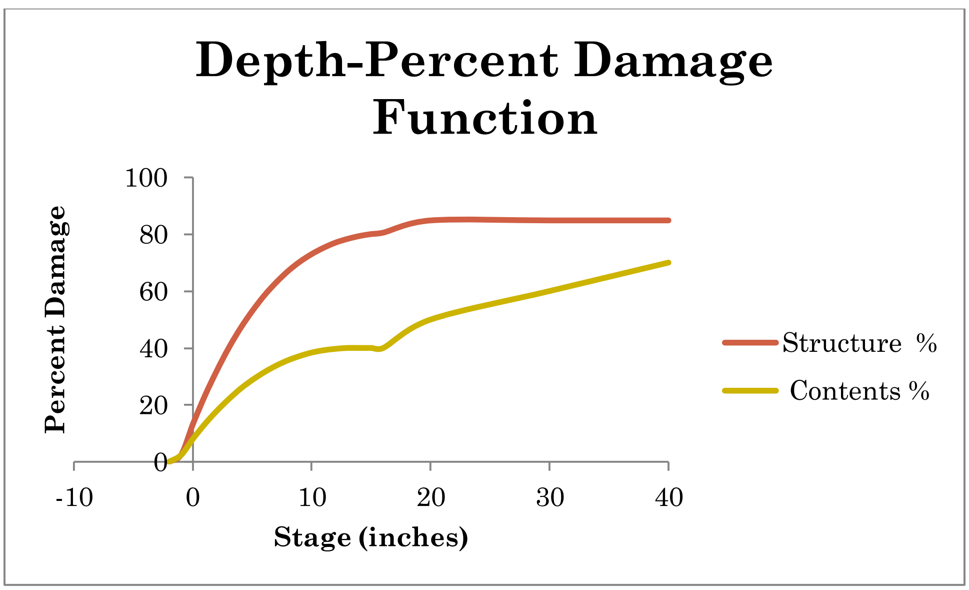


[7] Federal Emergency Management Agency (

[8] http://waterdata.usgs.gov/usa/nwis/uv?08158000

For this analysis, generalized curves for residential structures were developed by the Colorado River Authority. The relationships used in this study are based upon generalized curves compiled by the U.S. Federal Emergency Management Agency, Flood Insurance administration. The next table displays the depth-percent damage relationship for the most prevalent structure type (single residential). The other values can be estimated using a linear regression relationship.

Stage inche m	Structure %	Contents %	Stage inche m	Structure %	Contents %
-2	0	0	9	70.5	37.2
-1	2.5	2.4	10	73.2	38.4
0	13.4	8.1	11	75.4	39.2
1	23.3	13.3	12	77.2	39.7
2	32.1	17.9	13	78.5	40
3	40.1	22	14	79.5	40
4	47.1	25.7	15	80.2	40
5	53.2	28.8	16	80.7	40
6	58.6	31.5	20	85	50
7	63.2	33.8	30	85	60
8	67.2	35.7	40	85	70



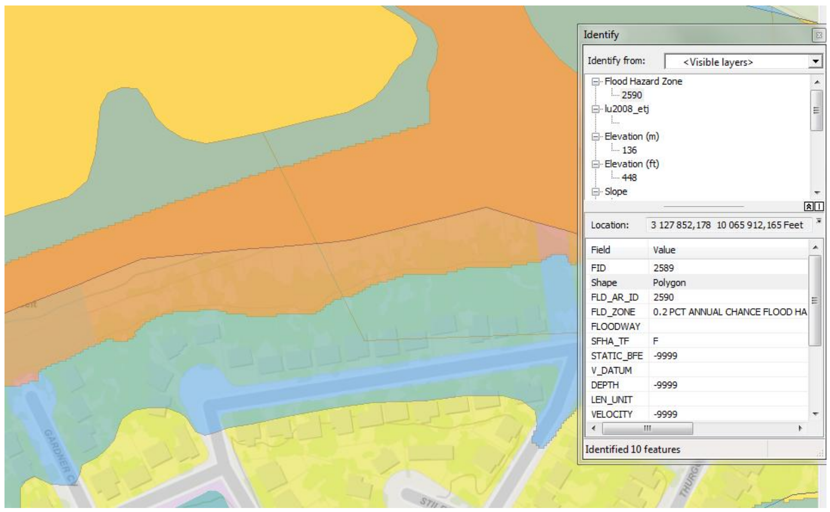
This model applies only for residential house and also for industrial/commercial or civic building, but not for open space and transportation areas. Also remained that the losses by cessation of economic activities of industrial or commercial building are not taken into account in this study.

4. Results

I use a 0.2 percent annual chance exceedance (data available on city of Austin website).

The first step is to integrate the floodplain on ArcMap software and also the land use map and value map. Then we can compute damages using a raster calculator using the flood-damage relationships developed below.

For instance, on Thurgood Avenue, we obtain the following results:



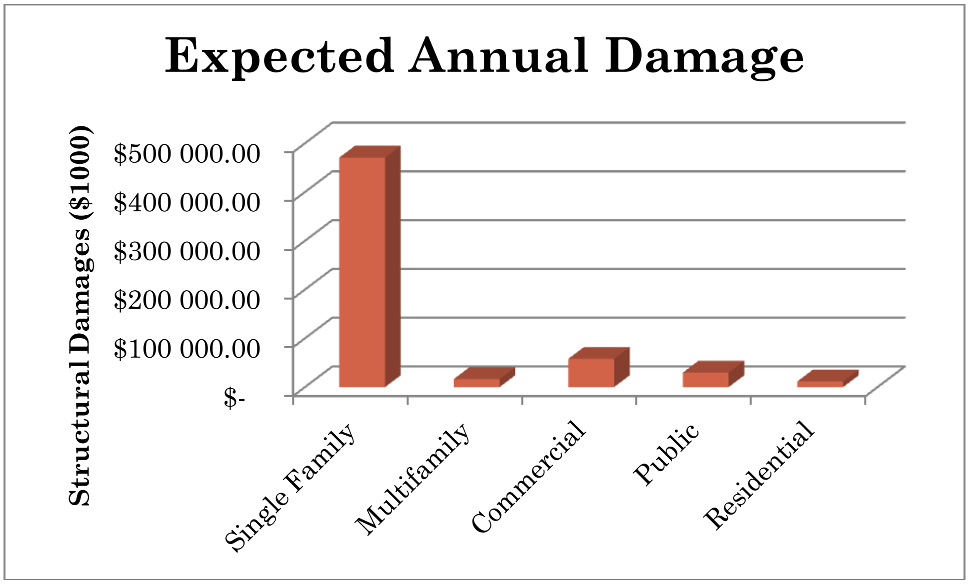
This can be summarizing on:

Thurgood Avenue	
Land Use Layer	100 = Single Family
Market Value Layer	$ 450 765.00
Flood Plain Layer	0.2 PCT ACE
	1 foot
Building%	77
Content %	32
Losses	$ 347 089.05

For this area, there is one single family house which is affected by a 0.2 % Flood. The depth is 1 foot so the % of losses if 77% for building and 31% for content. The land market value is $450,000 so the expected annual damages for this area are $350,000.

If we collect all the data of all the area of Austin, we obtain the following table in $1000.

	Number	Structure	Content	Total
Single Family	932	$ 313 844.00	$ 156 923.00	$ 470 767.00
Multifamily	45	$ 11 058.00	$ 5 529.00	$ 16 587.00
Commercial	85	$ 32 552.00	$ 25 471.00	$ 58 023.00
Public	40	$ 21 154.00	$ 8 583.00	$ 29 737.00
Residential	403	$ 5 445.00	$ 6 206.00	$ 11 651.00


Expected Annual Damage
Structural Damages ($1000)
$500 000.00
$400 000.00
$300 000.00
$200 000.00
$100 000.00
$-
Single Family
Multifamily
Commercial
Public
Residential

5. Conclusion

To conclude, the cost analysis of a flood can be leaded of several ways. Depending of the goal of the study, the parameters taken into account or the losses considerate will not been the same. An insurance company will focus more on the buildings and contents whereas a governmental organization will focus more on the economic activities and lead a cost-benefit analysis.

I have tried to evaluate some losses (only properties) in the city of Austin. The main difficulty encountered was to collect significant data for a specific area. Lots of data are available but sometimes, data are missing or are not accurate enough.

I decided to lead a land used analysis first to estimate which parts of the cities were threatened. It appears that housing were the main threatened buildings. This could represent so lot of losses for insurance company, and require strong human and technical resources for civil protection. Prevention of flood or forecasting of flood is so important for the Travis County. A cost-benefice analysis of protection equipments could use these results to evaluate the efficiency of such constructions.

Glossary

1% Annual Chance Flood	To provide a national standard without regional discrimination, the 1% annual chance (100-year) flood has been adopted by the Federal Emergency Management Agency (FEMA) as the base flood for floodplain management and flood insurance purposes. A 1% annual chance flood (or base flood) has a 1% annual chance of being equaled or exceeded in any given year.
1% Annual Chance Floodplain	The 1% annual chance floodplain identifies areas that are expected to be inundated by the 1% annual chance flood. The 1% annual chance floodplain, shown on a Flood Insurance Rate Map, is also called a Special Flood Hazard Area, where the National Flood Insurance Program's floodplain management regulations must be enforced by the community as a condition of participation in the Program.
Base Flood Elevation (BFE)	BFEs are shown on a Flood Insurance Rate Map and represent rounded, whole-foot elevations of the 1% annual chance flood at selected locations along flooding sources that have been studied in detail. To reduce the risk of damage from floods up to the 1% annual chance flood, communities are advised to consider these elevations when issuing building permits for structures.
Digital Elevation Model (DEM)	A DEM is a file with terrain elevations recorded for the intersection of a fine-grained grid and organized by quadrangle as the digital equivalent of the elevation data on a topographic base map.
Flood Insurance Rate Map (FIRM)	The FIRM illustrates the extent of flood hazards in a community by depicting a variety of types of information. This information may include flood insurance risk zones, 1% and 0.2% annual chance floodplains, floodways, base flood elevations or depths, common physical features such as roads and streams, and the location of cross sections. New FIRM panels for North Carolina have been produced digitally, and the data shown on these panels are available in the public domain.
Flood Insurance Study (FIS)	The FIS is an examination, evaluation, and determination of flood hazards, and, if appropriate, corresponding water-surface elevations. The FIS includes the FIS Report, Flood Insurance Rate Map panels, flood profiles, and tables.
Floodplain Management	The operation of an overall program of corrective and preventive measures for reducing flood damage, including, but not limited to, emergency preparedness plans, flood control works, and floodplain management regulations.
National Flood Insurance Program (NFIP)	Administered by FEMA, the NFIP enables property owners in participating communities to purchase insurance protection against losses from flooding, provides a framework for a community's floodplain management ordinances, and identifies floodplain areas and flood risk zones.
Watershed	The area draining into a river, river system, or body of water.

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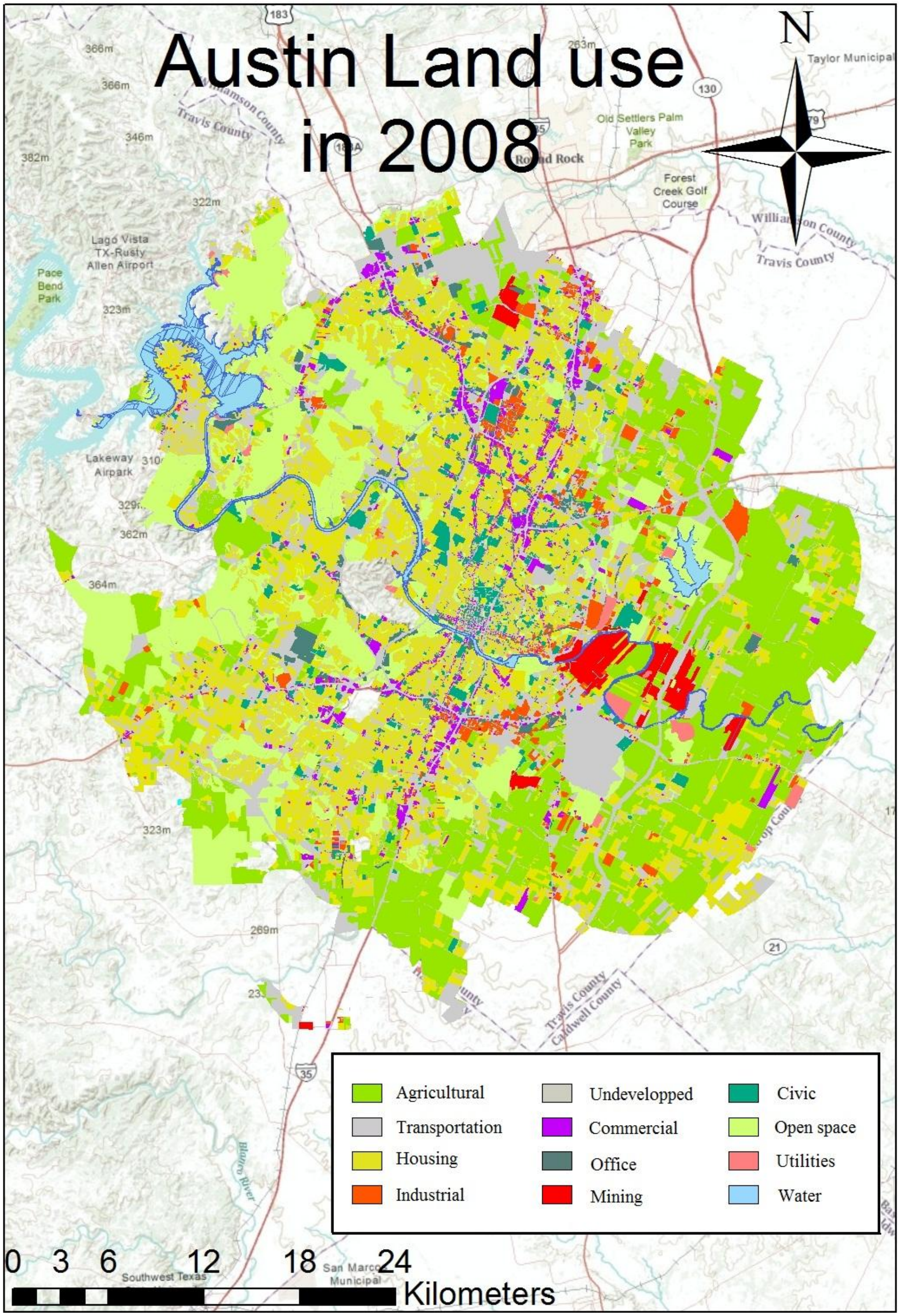
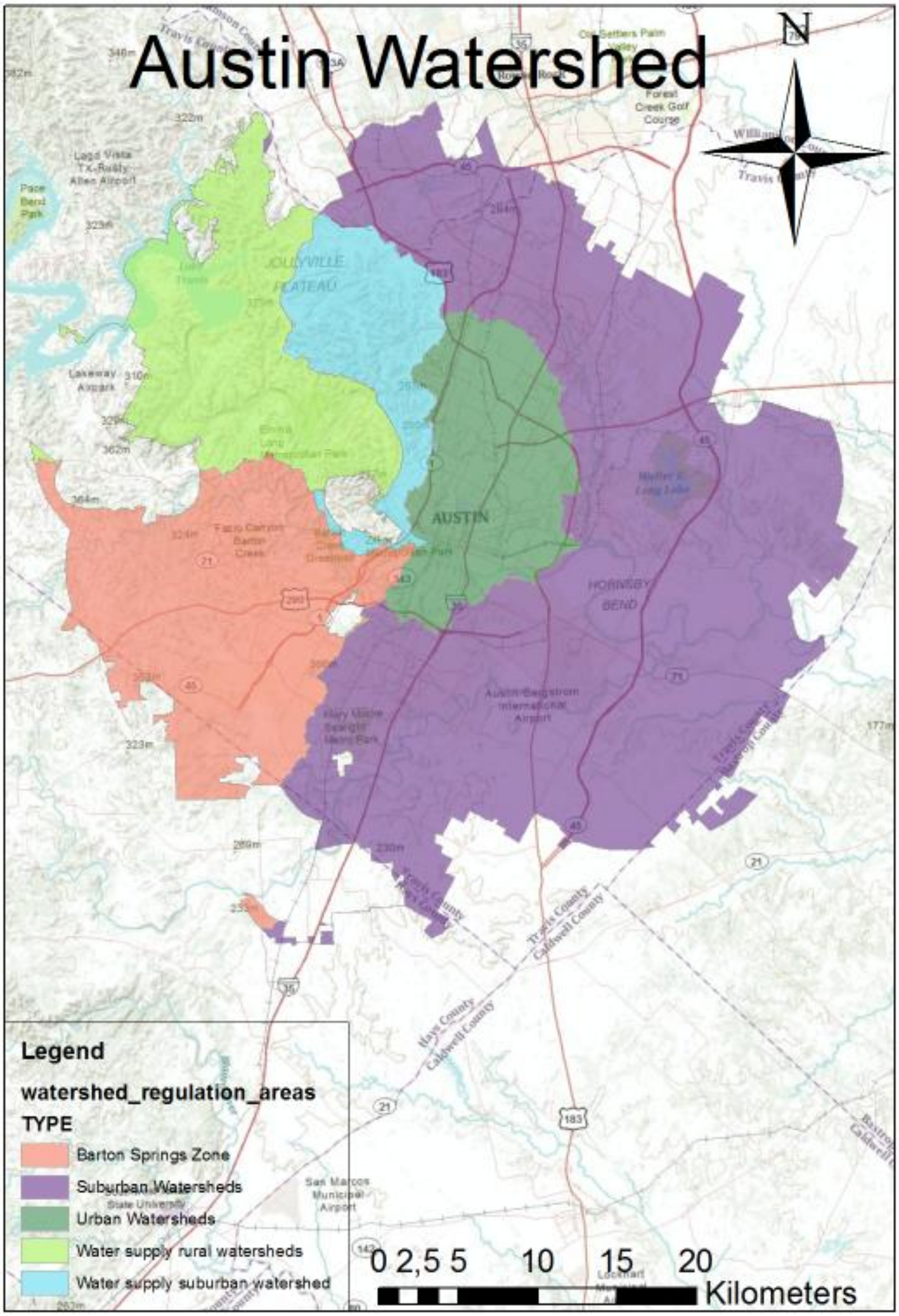
Annex 1 : Austin Land use in 2008



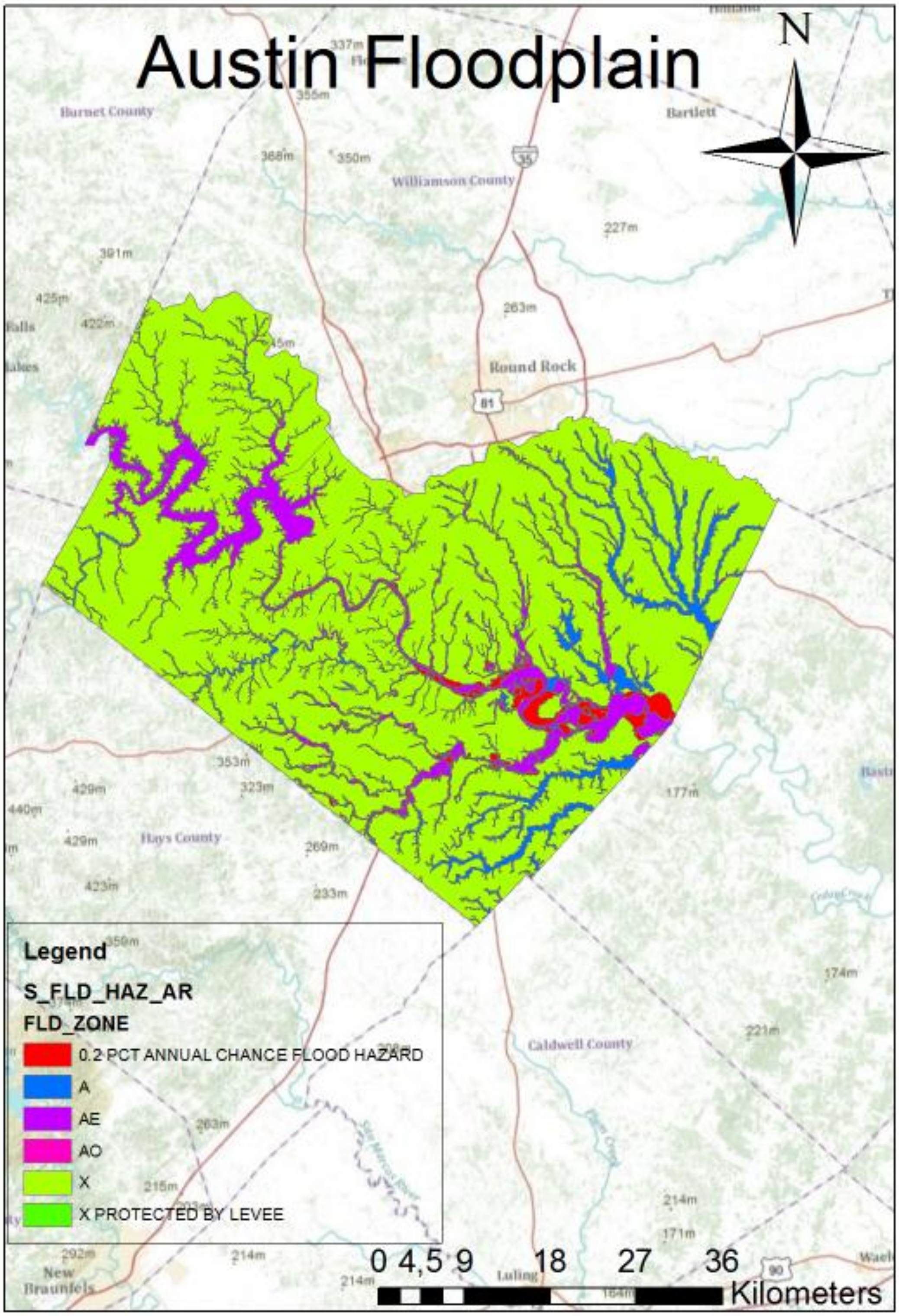
Land use of the city of Austin: layout from ArcMap10

Annex 2: Watershed of Austin



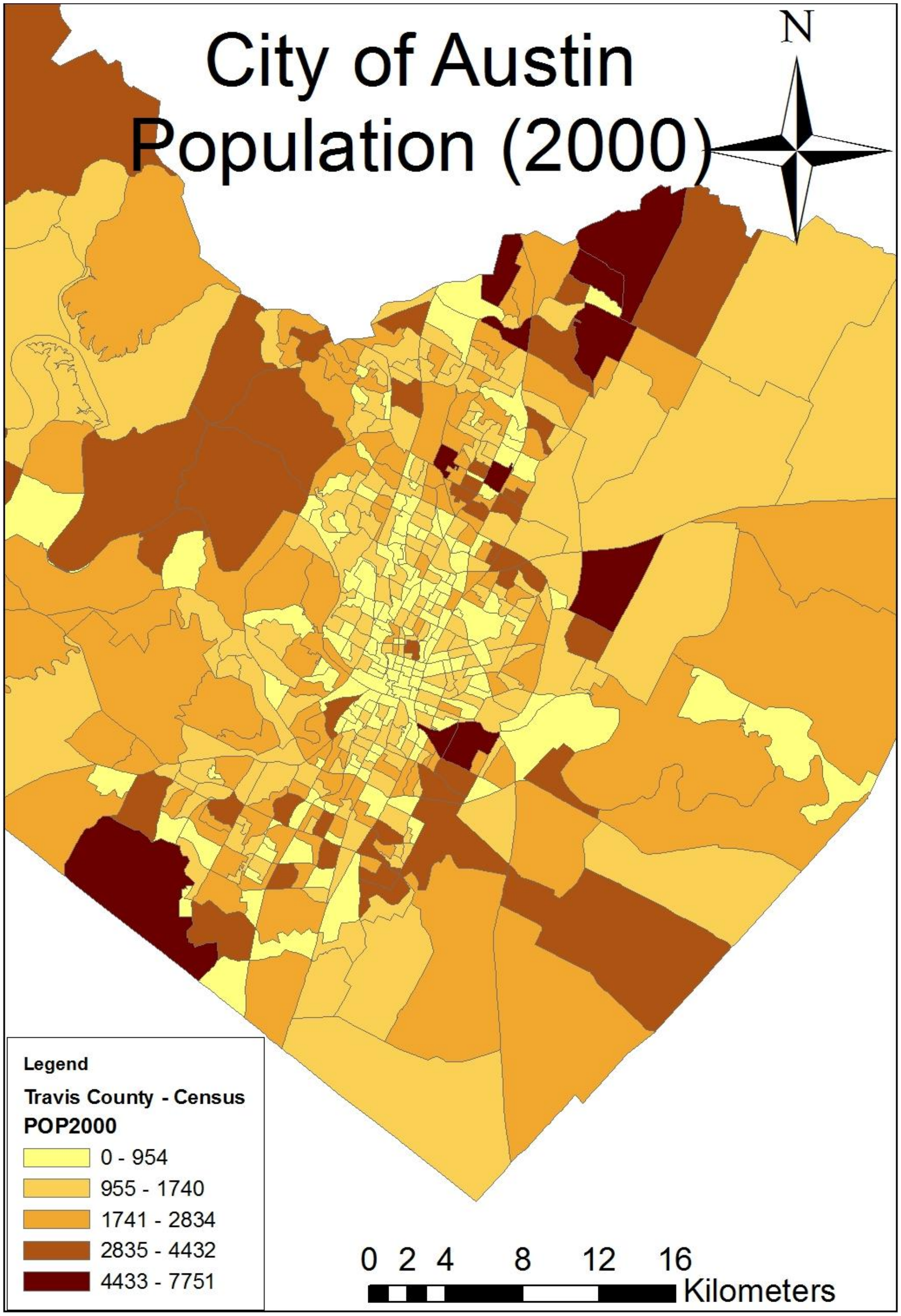
Watersheds regulation areas of the city of Austin: layout from ArcMap 10

Annex 3: City of Austin floodplain



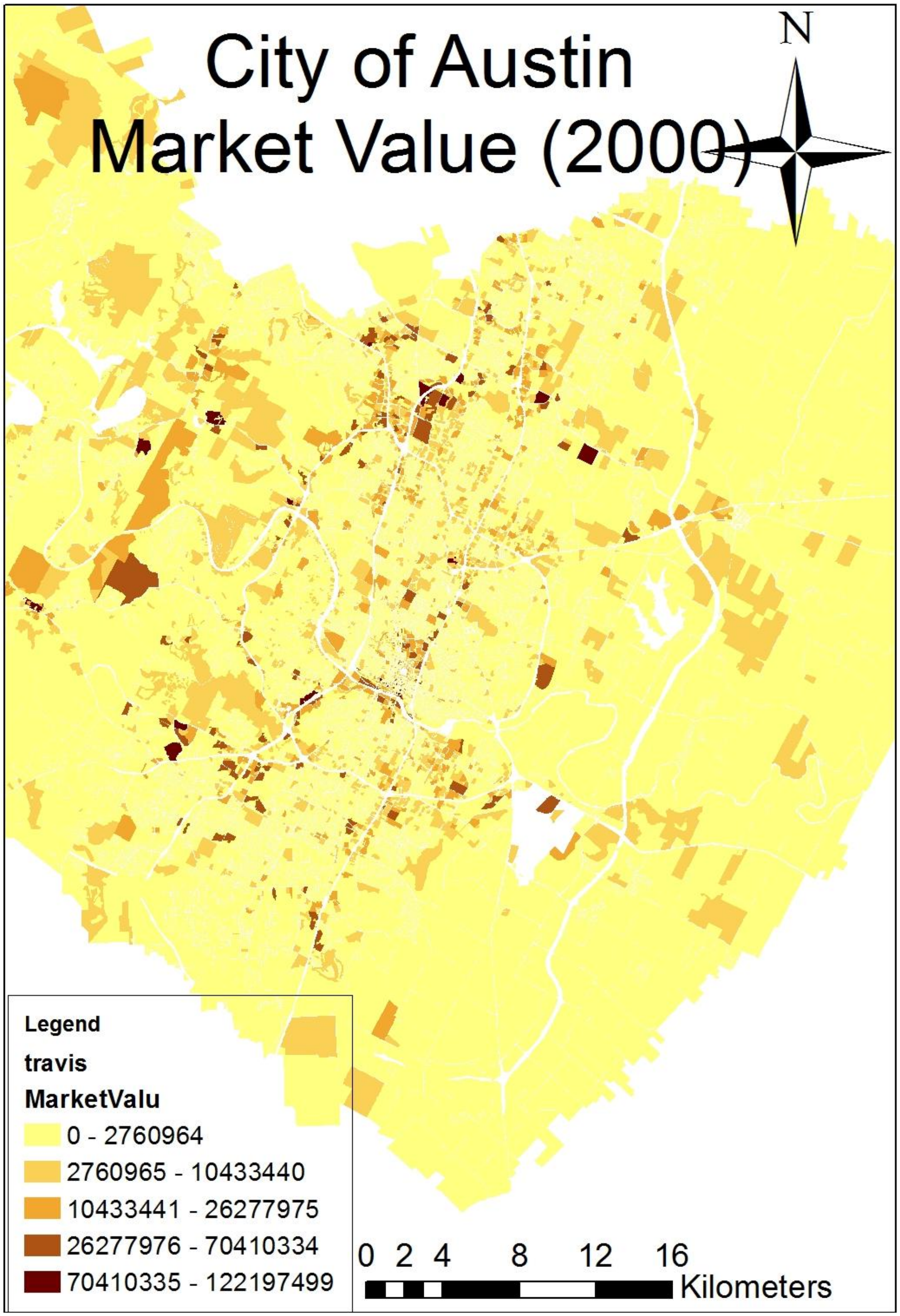
City of Austin Floodplain, layout from ArcMap 10

Annex 4: Population in 2000



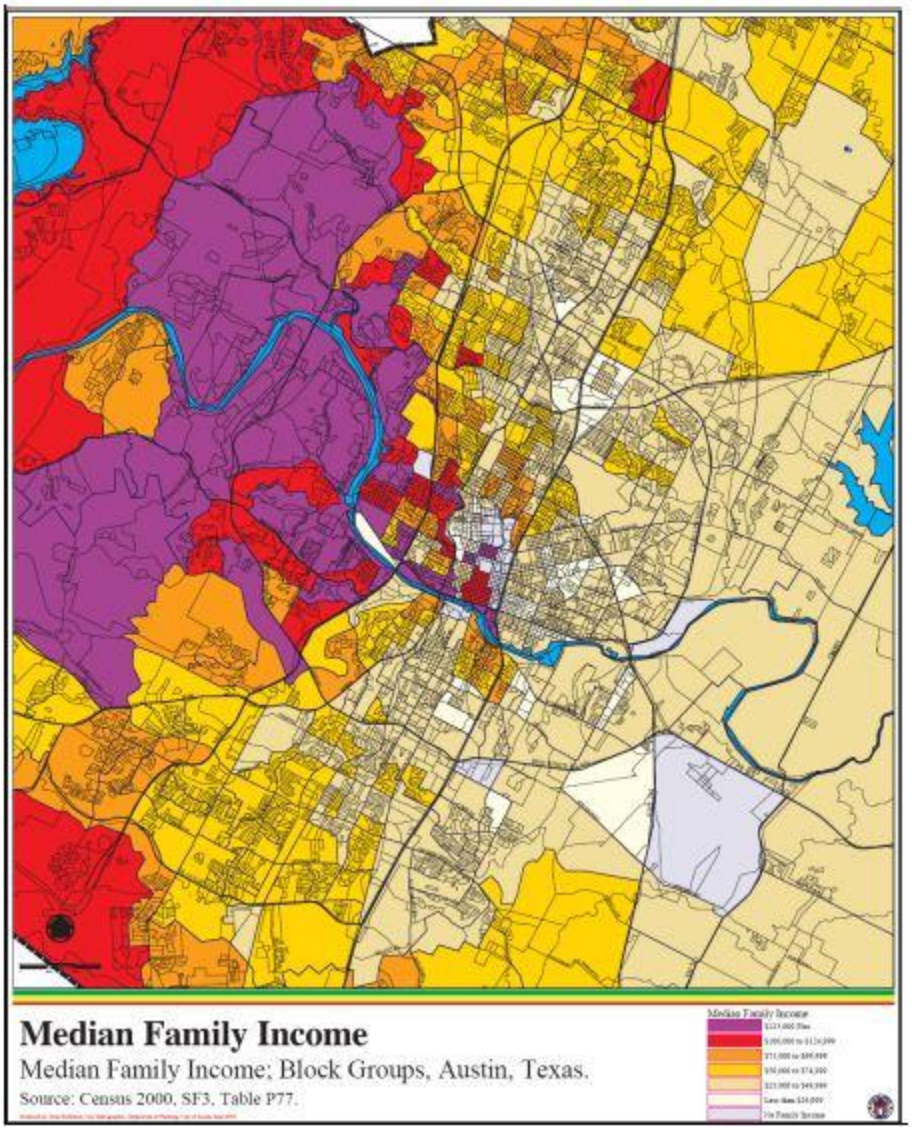
Population repartition in the city of Austin in 2000 – Layout from ArcMap 10

Annex 5: Market Value of city of Austin

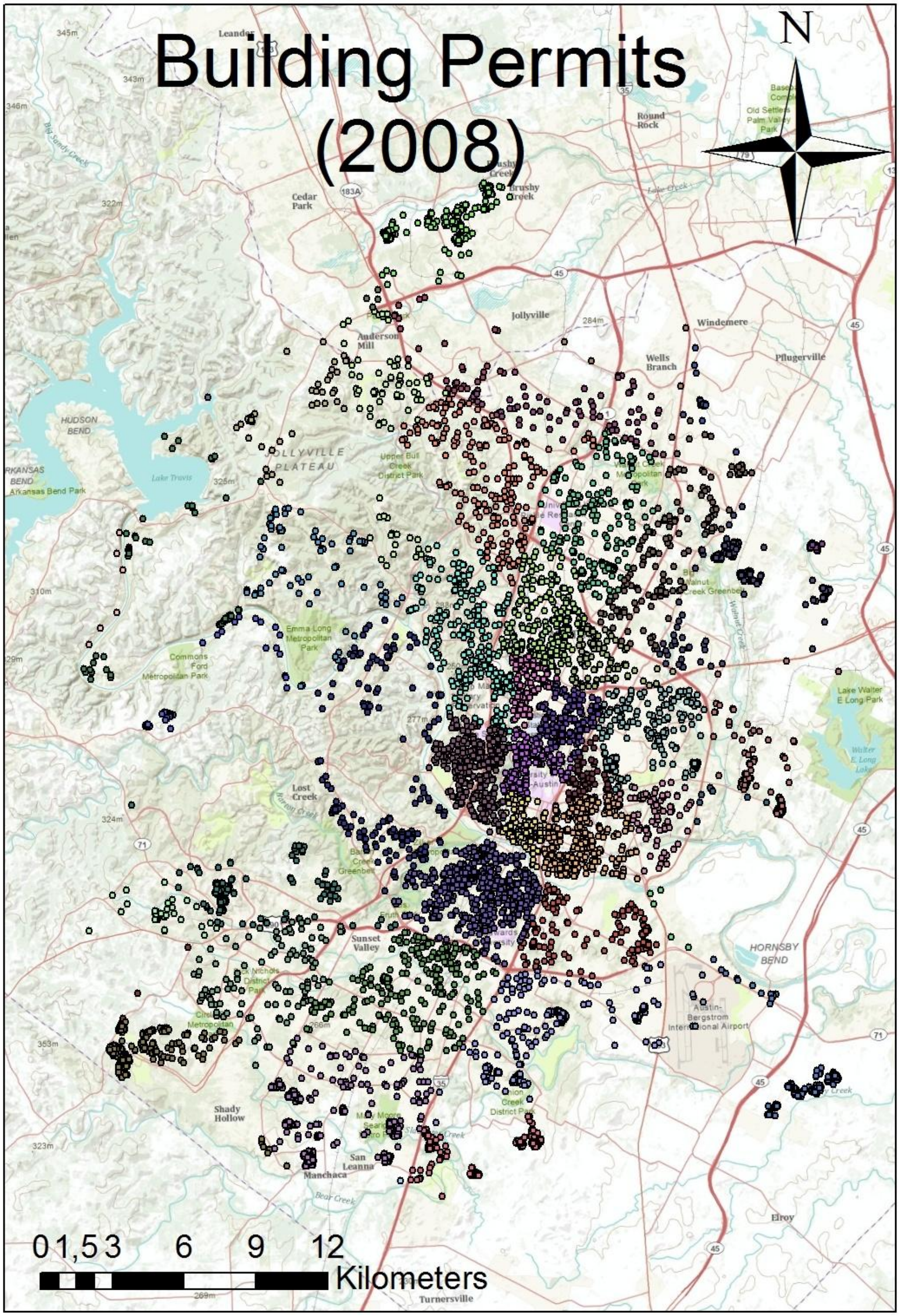


Land Value (market value) in 2000 – data from Census Bureau – Layout from ArcMap 10

Annex 6: Median Family Income in City of Austin (2008)



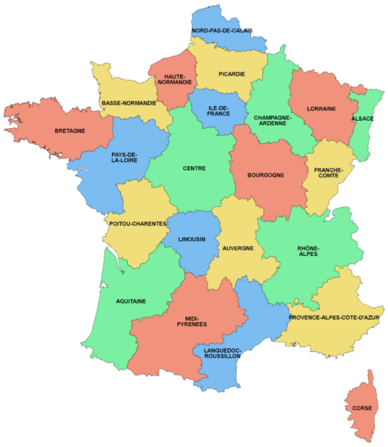
Annex 7: Building Permits in the City of Austin (2008)



Building Permis in 2008 – data from City of Austin – Layout from ArcMap 10

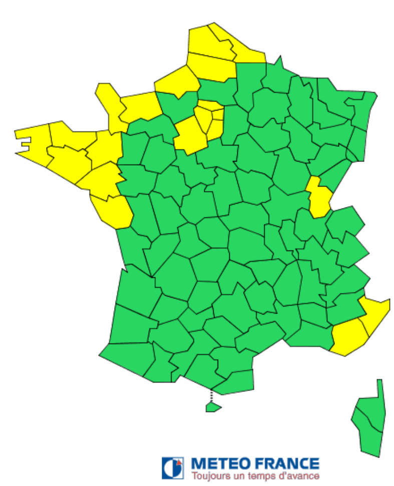
Additum: Flood Management in France

1. French territorial organization



France is divided in 26 "régions" and subdivided in 100 "départements". There are about 36600 "communes". Mayors these communes are responsible for public safety and are supported by the State which provides flood information and implements a flood alert system.

The territory organization for weather or flood-rain forecasting, used by Météo France is the same as the administrative one, there are 22 regions and so 22 regional centers. Moreover, there are several UH (Unité d'Hydrométrie: hydrometric units) all along the territory which provides data to the centers.



[9]

The territory organization for flood surveillance, used by SCHAPI in France is quite differently from the administrative one. There are also 22 SPC ("Service de prevision des crues": Service of flood forecasting). These areas follow the main rivers and watershed of France.

France is not spared by flood events as evidenced the 1910 great flood in Paris which is considered as a 100-year flood.

[9] Source : Geoportail : http://www.geoportail.fr/?l=EMPRISE-CRUE(55)

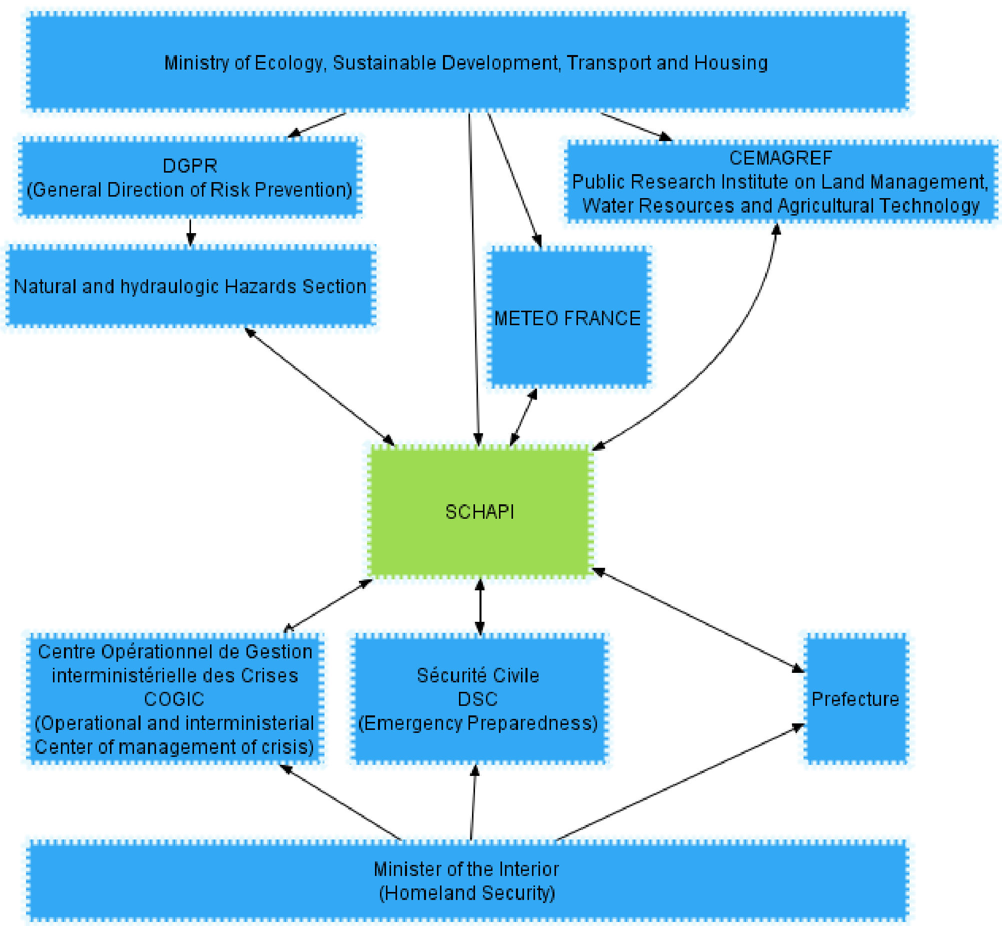
2. The SCHAPI Network

1. Introduction

SCHAPI stands for Service central d'hydrométéorologie et d'appui à la prévision des inondations or Central Service of Hydrometeorology and Support for Flood Forecasting.

SCHAPI is located in the heart of Toulouse in order to promote synergy between Météo-France and the scientific teams which are in Toulouse. The SCHAPI provides flood forecasting 24/24, 7/7. Meteorologist, hydrologist and computer scientists are working in direct contact and with a network of partners.

The SCHAPI is at the heart of an operational network of flood and rainfall forecasting. This network gather 22 SPC and 28 UH but is also in interaction with many scientific and technical partners as shown in the following map:

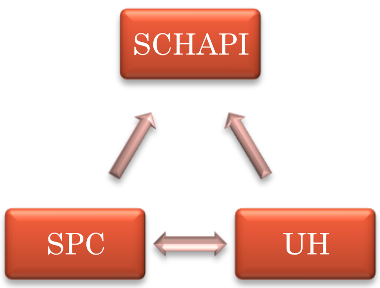


The SCHAPI holds an important role in flood forecasting. The first motivation for its creation in June 2003 was to better understand the threat of "Cévenol" thunderstorms[10] and flash flood. Its field of

[10] A Cévenol thunderstorms is a storm that occurs in the Cevennes (south of France)

intervention was quickly extended to all flood risk and included the modernization and management of the national database of hydrometric data.

This operational network is working according to the following map:



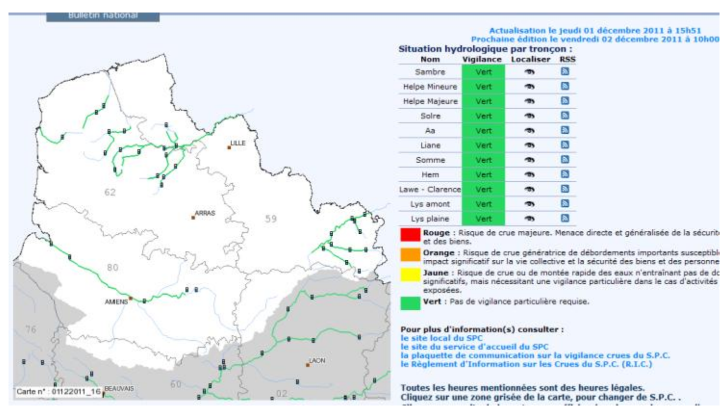
The SPC [11] provide forecasting for major watersheds. Forecasters of the 22 SPC analyze the rivers and the watershed fed. They deduce a level of alertness (level of risk) by segment/section streams, resulting in a color code (green for no particular risk, yellow is fast rising, orange is risk of significant damage, red is risk if serious damage).

2. SCHAPI information

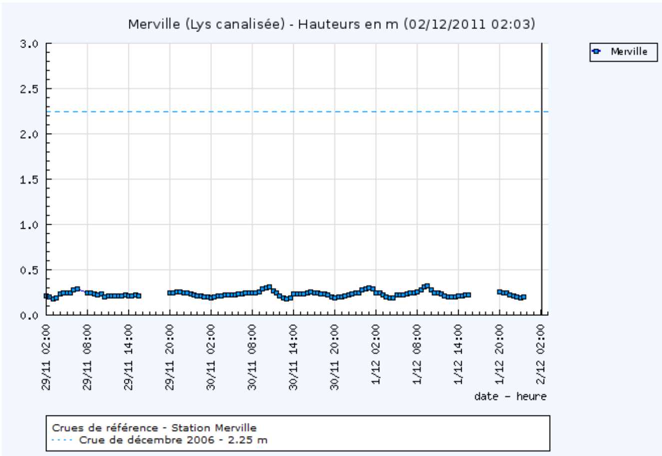
SCHAPI website (vigicrues.fr) provides all the information collected in a map updated twice a day (10 am and 4 pm) or more if necessary. There are 3 levels of details.

The first level is a national map. There is a color scheme used (green for no risk, 1 for small risk, 2 for moderate risk, 3 for high risk). That is color scheme used by Météo France that is well known and so easy to understand for French people.

The second level of detail is a regional map. The region concerned is one of the 22 SPC. The same color scheme is used. There is also the possibility to see details for sections. SCHAPI watch about 20,000 km of sections of rivers in Metropolitan France.



[11] Remind : Service of flood forecasting.



The third and last level of detail is the water level (height) or flow of a station (UH) which is on a section of a river. There is possibility to display the rate of flow or height of other stations of the same section. The dotted curve is the data of the last significant flood.