Flood Risk Assessment

21.12.2011

Menno Straatsma
Lasha Sukhishvili
Nodar Tkhelidze

Report

1. Introduction

There are about 26000 rivers in Georgia. Sum length of all of them is about 70000 km. 99.4% of all rivers are shorter than 25km. The most rivers are in western Georgia. Average annual discharge of all rivers in Georgia is about 62 km^3 and 78% of them are flowing into the Black Sea.

Top 5 rivers according to annual average discharge (km^3):

1. Rioni - 13.22;
2. Tchorokhi – 8.57;
3. Mtkvari (neat Tbilisi)- 6.5;
4. Enguri – 6.08;
5. Kodori – 3.97.

The longest river is Alazani – 421 km in Georgia and whole length is 425 km. River Mtkvari`s length is 383 km in Georgia. The next river is Iori, its length is 343 km in Georgia and the whole length is 407 km. And the third river is Rioni – 327 km. Rioni is the longest river among the rivers that start and end in Georgia.

Rivers in Georgia has different feeding sources. They might be: precipitation, groundwater, eternal snow and glacier melting or all of them.

Rivers in Georgia are characterized by flood and flashflood natural hazards. Flashfloods are formed because of heavy rainfall and sudden warming of air temperature during snow melting period. Floods are depended on: water amount in snow cover accumulated in winter; Intensity of air temperature raise; Amount on rainfall during snow melting period and etc.

Rivers that are originated from melted water of eternal snow and/or glaciers of Caucasus have a flood phase during 160-180 days in warm seasons. Their discharge minimum is in winter.

Rivers that are originated from the southern slopes of Caucasus where the seasonal snow exists are characterized by spring-summer flood and autumn flashflood (because of rain) phases. Their discharge minimum is in winter.

Rivers that are originated from the western part of central Georgia`s mountains are characterized by spring floods and summer-autumn flashfloods. Their maximal discharge is possible in every season except winter.

Rivers in Black Sea region that are formed in Kolkheti lowland, Caucasus mountains (nearby kolkheti lowland) or in Meskheti range are characterized by flashfloods caused by rainfall.

There are very widely presented rivers characterized by spring flood and autumn flashflood phases in Georgia. Mostly they are presented in eastern Georgia and in some cases in Atchara region. Spring floods are formed because of snow melting and also from rainfall. Autumn flashflood is formed by rainfall. Minimal discharge is in winter and sometimes because of irrigation processes in summer.

Rivers with spring flood phase are in Javakheti region. Mostly they are formed by ground water and snow melted water. Because of high share of ground water, these rivers have more or less stable discharge during the whole year.[1]

[1] D. V. Kochiashvili – Geography of Georgia. Tbilisi 2003

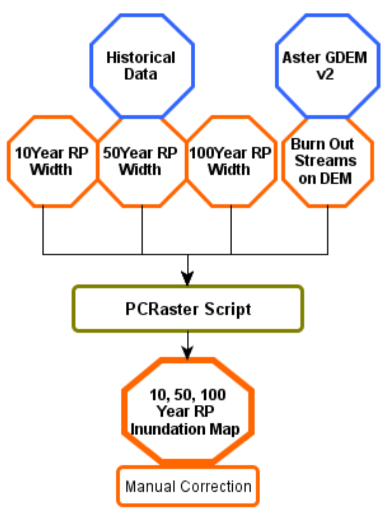
2. Research Methodology

The first step is to calculate inundation width by the processing of historical data derived from hydrological catalog for 10, 50 and 100 years return period (RP). Than we interpolated 10, 50 and 100 RP point data to raster by IDW interpolation.

PCRaster script was used in order to determine the height above the river from DTM. It determines the location of the main river based on the stream order of the water courses. Then the height above river for each location in the study area is computed by forcing the catchments to have their mouths at the location of the river. In a final step the map with the heights above the river is reclassified into three broad classes, smoothed, and non-attached clumps of the map are removed. Data is based on the ASTER GDEM v2, see http://www.gdem.aster.ersdac.or.jp/[2]

Manual corrections were done for specific areas- some areas were freed from inundation and some were added. Corrections were done according to personal knowledge and information from local people.

Source of validation is historical data from media and cross sections for several rivers. Media data was in text format and was converted to raster using community shapes. Cross sections were processed and widths were calculated for 10, 50 and 100 year RP. Validation using media data was performed visually and for cross section – digitally that means: if we have max river width less than 100m and on the same place inundated area (generated using PCRaster script) was more than 1 or sometimes 2[3] pixels (100-200m) it means that there is error.



[2] The method is based on De Roo et al. (2007) Potential Flood Hazard and Risk Mapping at Pan-European Scale. Adjustments are made based on local hydrostations

[3] Sometimes cross section covered 2 pixels but they were not filling whole 2 pixels. This caused that 2 pixels were used to represent inundated area. Sometimes inundation started from upper areas and flowed down to the area of cross section. In this case even if inundation width, according to cross section, is no more 100-150m the same place is represented by more than 2 pixels. We think that such kind of cases are normal.

3. Baseline Data and Preprocessing

3.1. Data Sources

Very few data was available for this hydrological task. Hydro observation data is very old and sometimes less reliable.

- There is an observation data catalog called “Main Hydrological Characteristics” issued during Soviet period. This is the main data source in Georgia, but because of some objective cases we couldn`t get it. Fortunately there is another catalog book that is based on previous one - Leila Tsanava`s “Catastrophic floods, flashfloods and mudflows in Georgia” and represents just main hydrological characteristics of 108 rivers;

- Several cross sections were collected from National Environmental Agency (NEA), CENN and Ilia State University (Institute of Earth Sciences);

- Aster GDEM v2 was downloaded from http://demex.cr.usgs.gov/DEMEX/. This DEM is produced by Terra Satellite;

- Media information about flood and flashflood;

- Hydro Network derived from 25k soviet topographical map.

3.2 Data Description and Preprocess

3.2.1. Aster GDEM v2

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) was developed jointly by the U.S. National Aeronautics and Space Administration (NASA) and Japan's Ministry of Economy, Trade, and Industry (METI).

The ASTER GDEM covers land surfaces between 83°N and 83°S and is comprised of 22,702 tiles. Tiles that contain at least 0.01% land area are included. The ASTER GDEM is distributed as Geographic Tagged Image File Format (GeoTIFF) files with geographic coordinates (latitude, longitude). The data are posted on a 1 arc-second (approximately 30–m at the equator) grid and referenced to the 1984 World Geodetic System (WGS84)/ 1996 Earth Gravitational Model (EGM96) geoid.

Updates in GDEM V2[4]:

- Finer horizontal resolution - The elevation is calculated by image matching of ASTER stereo pair. The kernel size for image correlation matching is changed to 5 by 5 pixel from 9 by 9 pixel.
- Water body detection - GDEM ver. 1 could detect lakes larger than about 12km2. This improves to 1km2 in version 2.
- New observed data - GDEM version 2 incorporates new ASTER data observed after September 2008. The voids and artifacts caused by lack of ASTER data will be improved.
- Resolution improves to 70m from 110m (version 1).
- Offset reduces to -0.7m from -6m (version 1).
- Voids in northern area decrease.
- Artifacts mostly disappear.
- Lakes are perfectly flat.

While the ASTER GDEM 2 benefits from substantial improvements over GDEM 1, users are nonetheless advised that the products still may contain anomalies and artifacts that will reduce its usability for certain applications, because they can introduce large elevation errors on local scales. The data are provided "as is" and neither NASA nor METI/ERSDAC will be responsible for any damages resulting from use of the data[5].

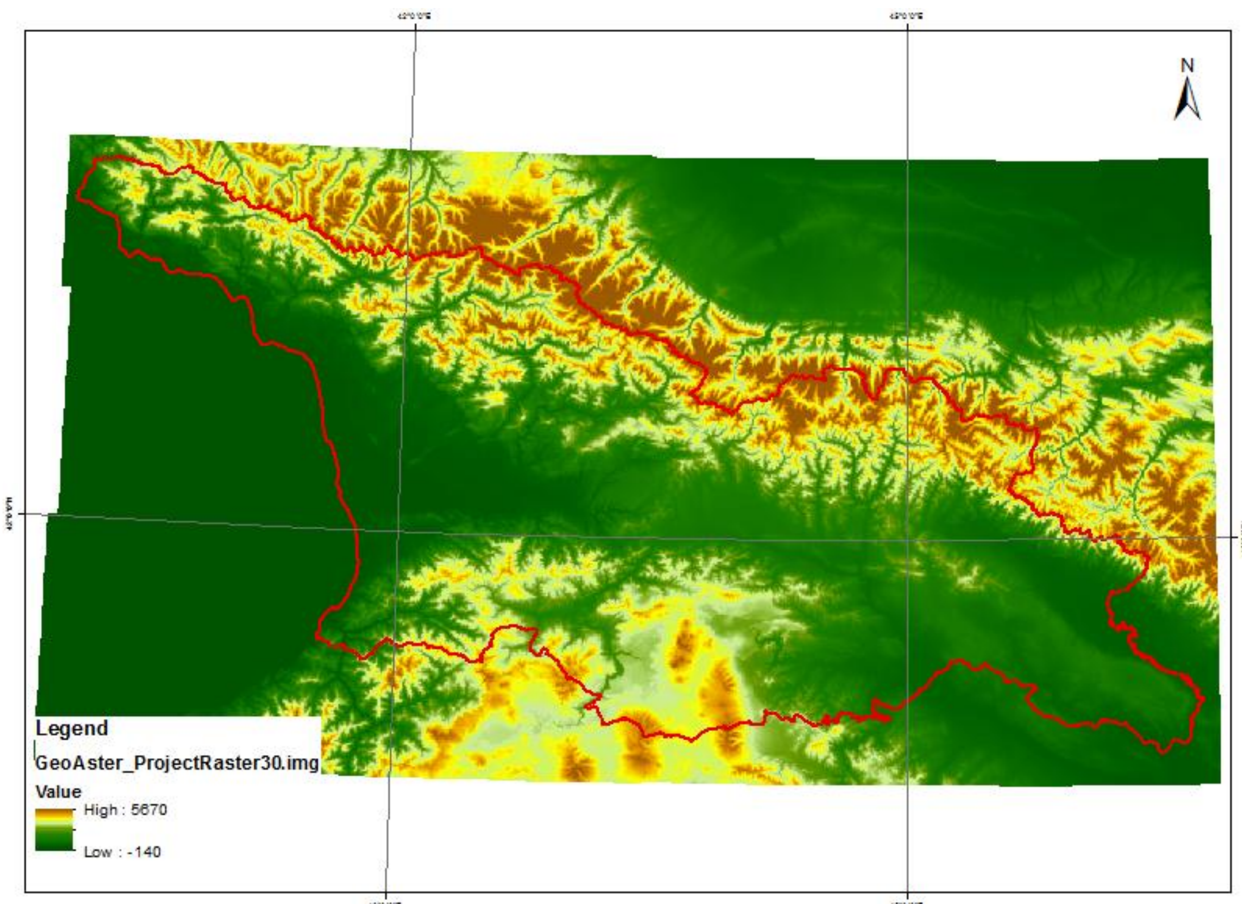
According to our quality check process between Aster GDEM v2 and topographic maps 25k and 50k, also digitized point elevations from 50k topo map, Aster GDEM v2 elevation was very close to elevation points from 25k topo map. 50k map (paper and digitized) had relatively big errors[6].

[4] Tetsushi Tachikawa, Masami Hato, Manabu Kaku, Akira Iwasaki - Characteristics of ASTER GDEM Version 2
[5] https://lpdaac.usgs.gov/content/view/full/11033
[6] See additional file —Which Dem Is Better

ASTER Global DEM (GDEM) data are subject to redistribution and citation policies. Before ordering ASTER GDEM data, users must agree to redistribute data products only to individuals within their organizations or projects of intended use, or in response to disasters in support of the GEO Disaster Theme. When presenting or publishing ASTER GDEM data, users are required to include a citation stating, "ASTER GDEM is a product of METI and NASA."

We decided to use Aster GDEM v2. This DEM was downloaded from http://demex.cr.usgs.gov/DEMEX/ Downloaded data represents whole Caucasus region and by default was divided into three parts. We used ArcGIS Data management tool “mosaic to new raster” and received one raster from three.

Figure 1: 30m pixel size DEM



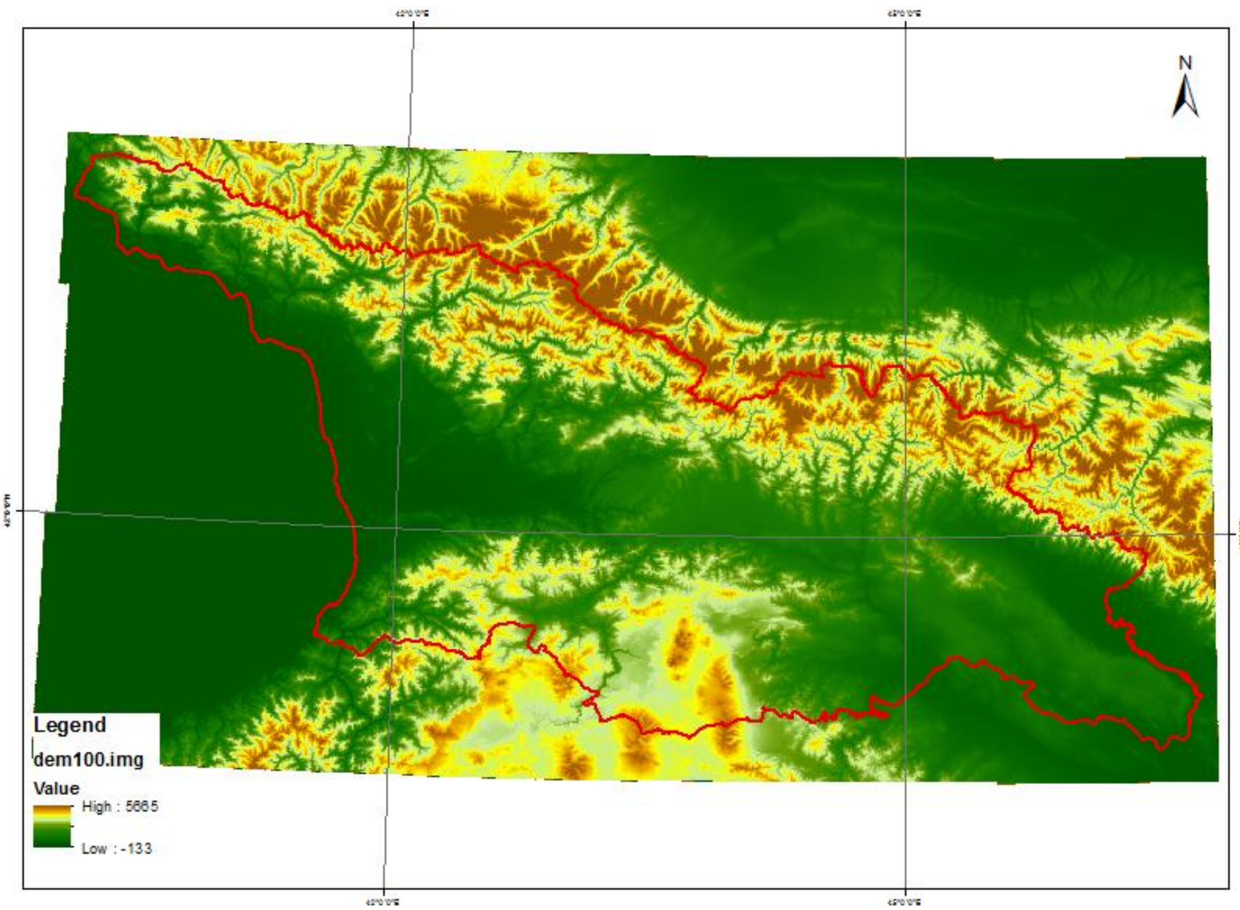
The min. elevation value from our DEM is -140m. Of course, -143m is anomaly but these errors are in the Black Sea area and also on the most NE part of DEM. When we extracted DEM using Georgia`s state boundary contour we have got 0m as minimal elevation.

The max. elevation value is 5670m, it represents the highest mountain peak of Caucasus - Ialbuzi (Elbrus), It`s elevation is 5642m[7]. Offset is 28m.

[7] The World Book Encyclopedia—Page 317 by World Book, Inc

DEM was resampled to 30m pixel and reprojected to WGS 84, N38. Later we resampled it from 30m to 100m pixel size. On all steps resampling technique was “cubic”.

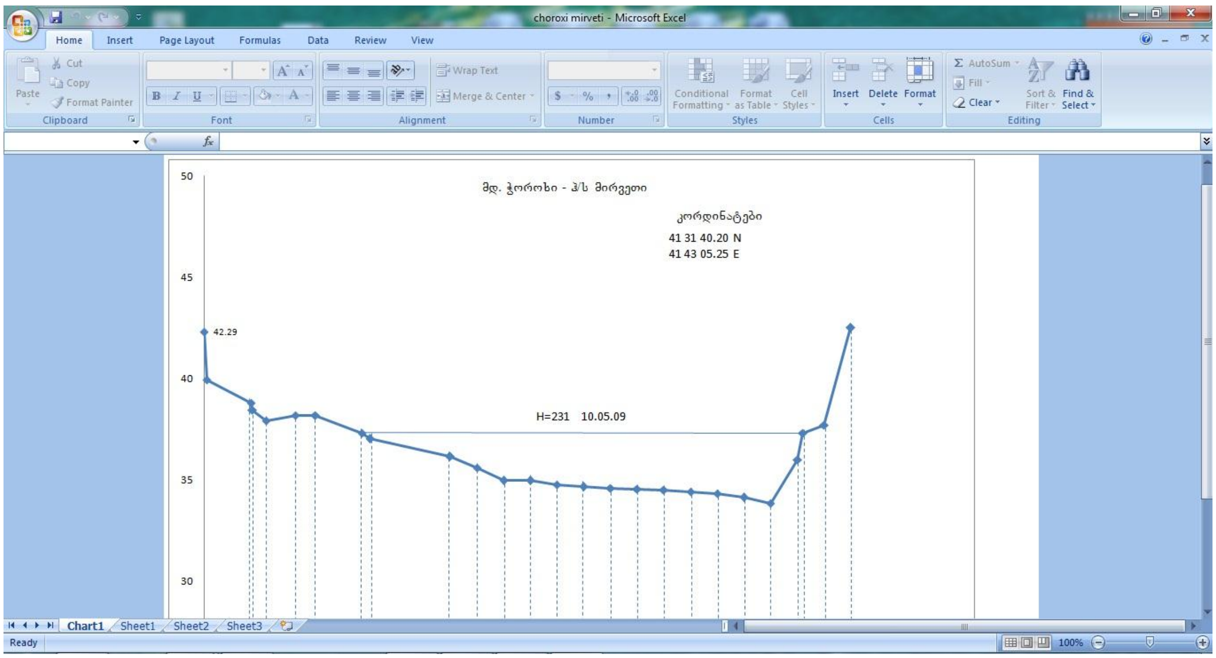
Figure 2: 100m pixel size DEM



3.2.2. Cross Sections

Cross sections were collected from NEA, CENN and Ilia State University. Should be mentioned, that they are not many. We have cross sections for the following rivers: Rioni, Tchorokhi, Alazani, Enguri, Kvirila, Pshavis Aragvi, Mashavera, Mtkvari, Shavi Aragvi, Tekhuri and Khobistskali.

Figure 3: Cross Section

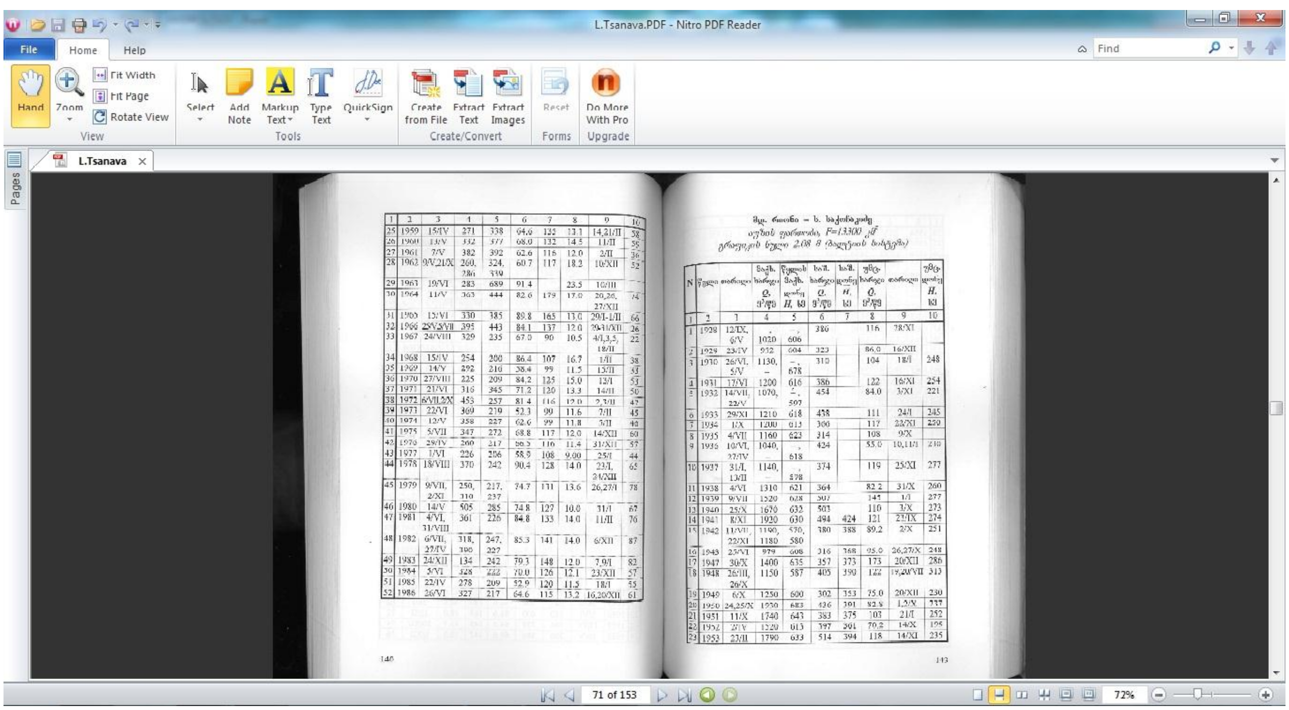


3.2.3. Leila Tsanava`s book “Catastrophic floods, flashfloods and mudflows in Georgia”

This book is based on “Main Hydrological Characteristics” catalog prepared during Soviet period. Here is represented following information:

River name;
Station name;
Basin area;
Date;
Maximal discharge (m^3/sec);
Maximal water level (cm);
Average annual discharge (m^3/sec);
Average water level (cm);
Minimal discharge (m^3/sec);
Minimal water level (cm).

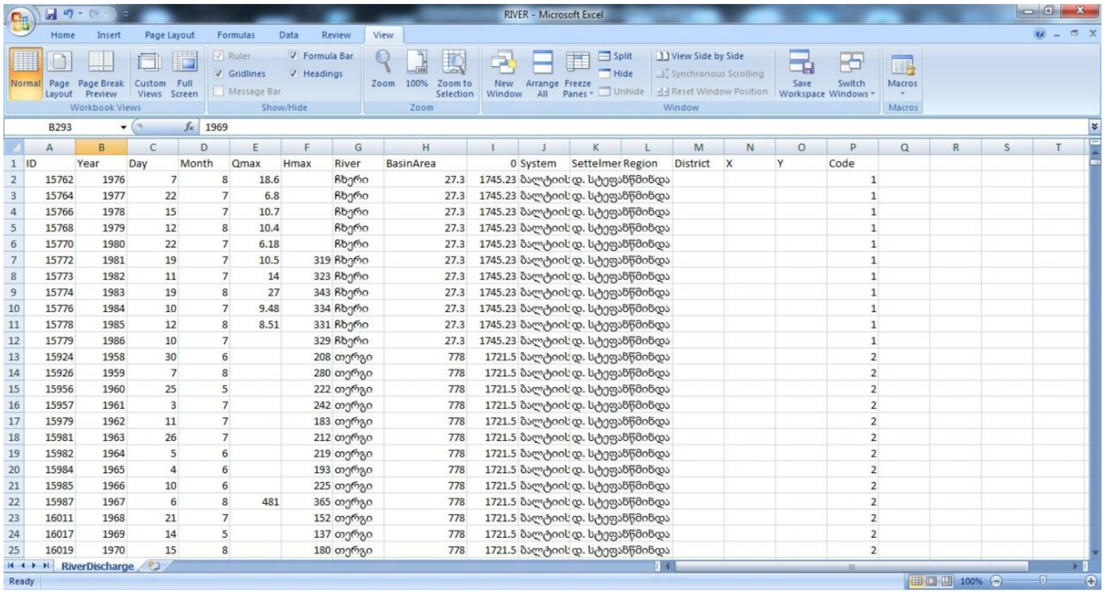
Figure 4: L. Tsanava - Catastrophic Floods, Flashfloods and Mudflows in Georgia



Sometimes some data were missing or there were some errors caused by mistype.

We have digitized the following kind of data from this book in MS Excel file: River name, data of observation, maximum annual discharge, maximum annual water level, station name and code.

Figure 5: Digitized hydro database



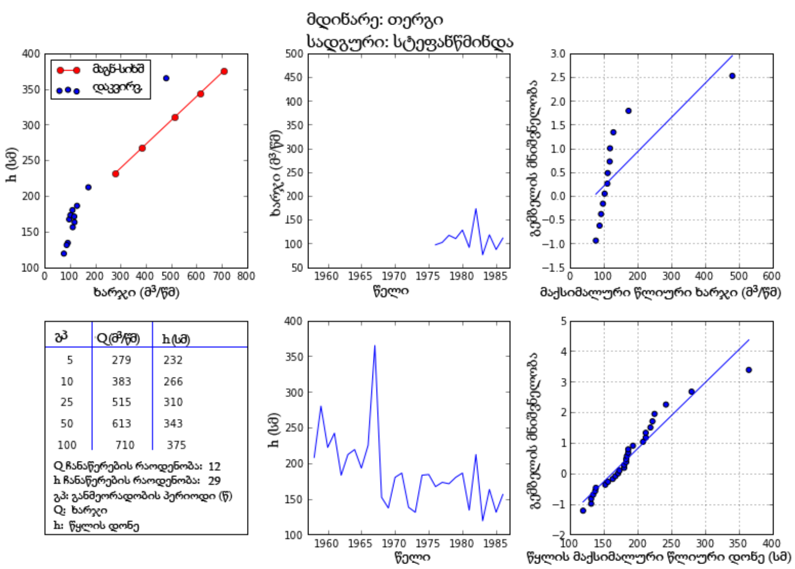
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	ID	Year	Day	Month	Qmax	Hmax	River	BasinArea	0	System	Settelmer	Region	District	X	Y	Code
2	15762	1976	7	8	18.6		ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
3	15764	1977	22	7	6.8		ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
4	15766	1978	15	7	10.7		ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
5	15768	1979	12	8	10.4		ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
6	15770	1980	22	7	6.18		ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
7	15772	1981	19	7	10.5	319	ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
8	15773	1982	11	7	14	323	ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
9	15774	1983	19	8	27	343	ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
10	15776	1984	10	7	9.48	334	ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
11	15778	1985	12	8	8.51	331	ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
12	15779	1986	10	7		329	ჩხერი	27.3	1745.23	ბალტიის	დ. სტეფანწმინდა					1
13	15924	1958	30	6		208	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
14	15926	1959	7	8		280	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
15	15956	1960	25	5		222	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
16	15957	1961	3	7		242	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
17	15979	1962	11	7		183	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
18	15981	1963	26	7		212	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
19	15982	1964	5	6		219	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
20	15984	1965	4	6		193	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
21	15985	1966	10	6		225	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
22	15987	1967	6	8	481	365	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
23	16011	1968	21	7		152	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
24	16017	1969	14	5		137	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2
25	16019	1970	15	8		180	თერგი	778	1721.5	ბალტიის	დ. სტეფანწმინდა					2

108 Hydro stations were geolocated and saved in ESRI shapafile. Each station was granted its unique code. The same codes were used in Excel file for digitized database. Later these codes were used for database joining purposes.

From the prepared data Gumbel Extreme value distribution was calculated. The objective of these distributions is to build the relation between the probability of the occurrence of certain event, its return period and magnitude.

Multigraphs with the data overview and Gumbel estimates were converted from English to Georgian. These plots were made in Python. We have checked the possibilities to visualize in Georgian using Python, or other software, but it didn`t work. And than we used graphical program. Here is result:

Figure 6: Multigraph translated to Georgian



3.2.4. Media information about flood and flashflood

It was important to analyze historical data, about already occurred flood and flashflood in Georgia. We had two main sources of information- The first was archived newspapers from National Library of Georgia, this data was starting from 1860s. Another source was book “Catastrophic Floods, Flashfloods and Mudflows in Georgia”

Figure 7: L. Tsanava - catastrophic Floods, Flashfloods and Mudflows in Georgia

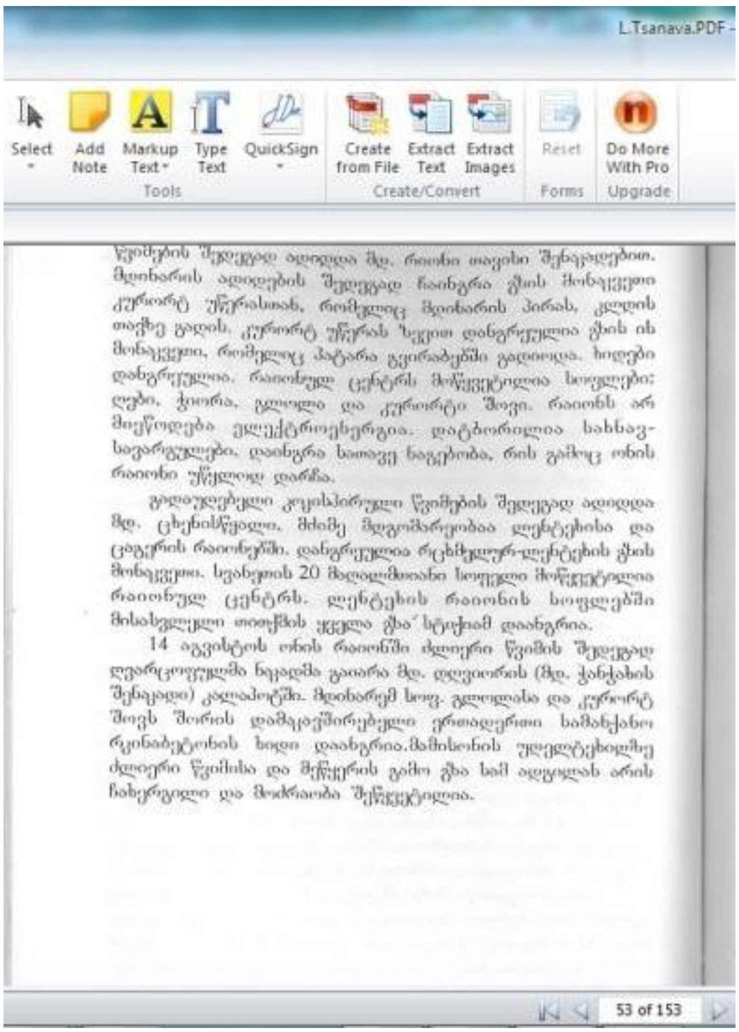
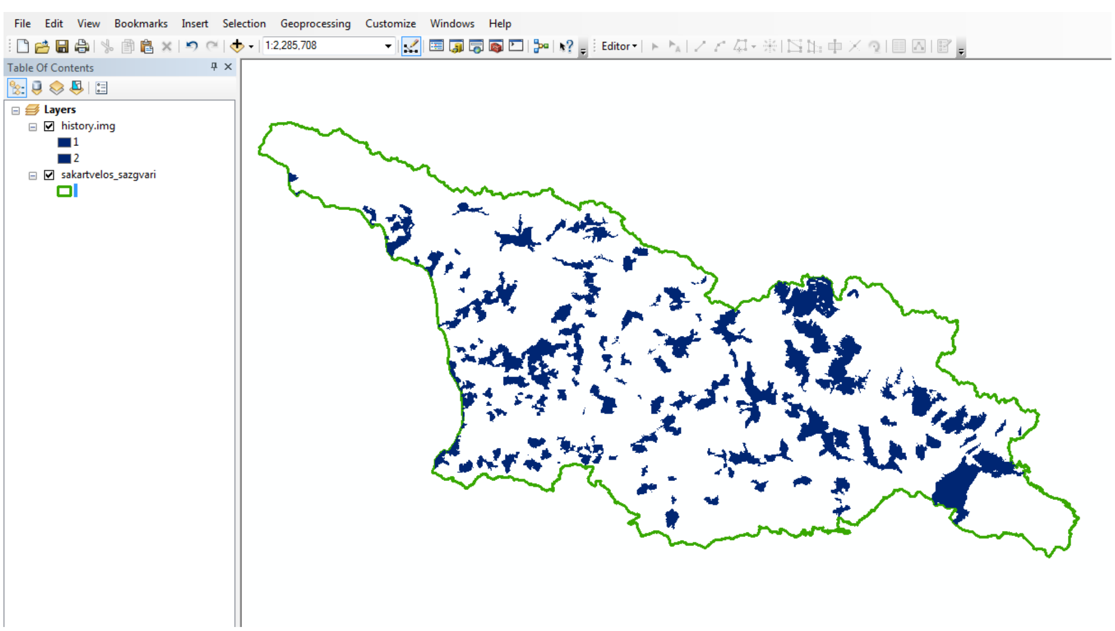


Figure 8: Newspaper "Iveria" XIXc

ივერია

Data was collected in MS Access file. Fields are describing location of hazardous event by community, district and regional level. On second stage we used database of settlement based on 1:50000 scale topographical map and joined polygonal shape file of communities with historical flood database. Unfortunately data that was located by region or district scale were not used, because in this case almost all Georgia was inundated and it wouldn`t give us any useful information. Database was converted to 100m pixel size raster.

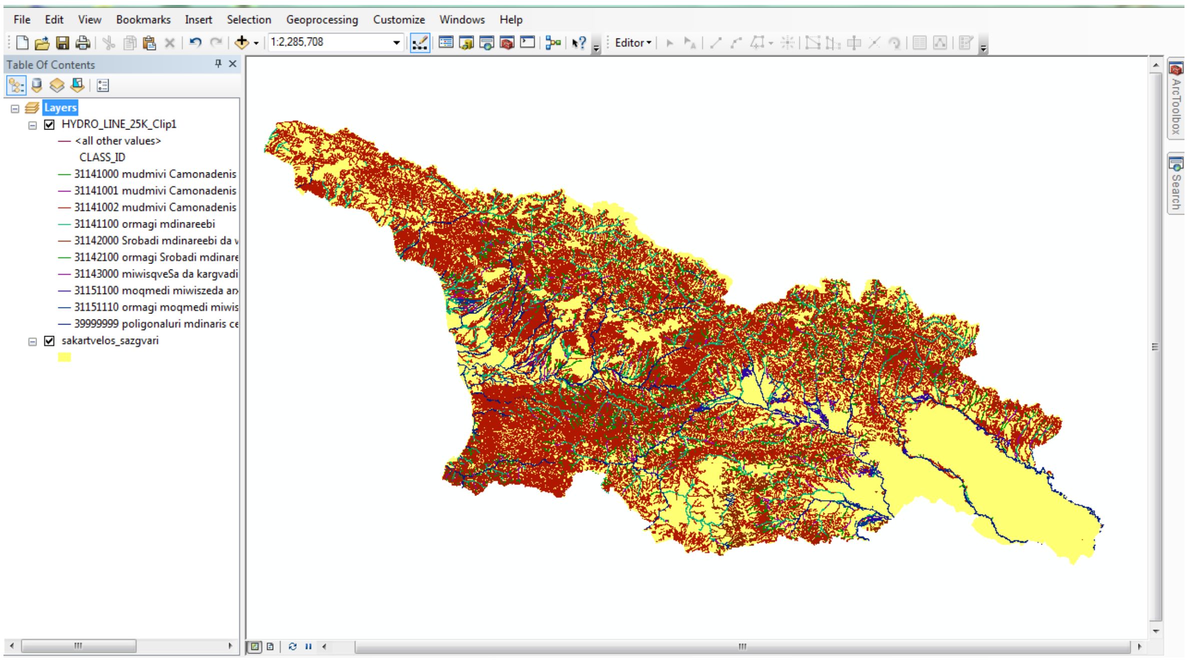
Figure 9: Raster created from media data



3.2.5 Hydro Network derived from 25k soviet topographical map

This geodatabase represents rivers, springs, temporal streams and channels derived from 25k Soviet topographical map.

Figure 10: Hydrolines geodatabase



This geodatabase was filtered and channels, springs and temporal streams were removed.

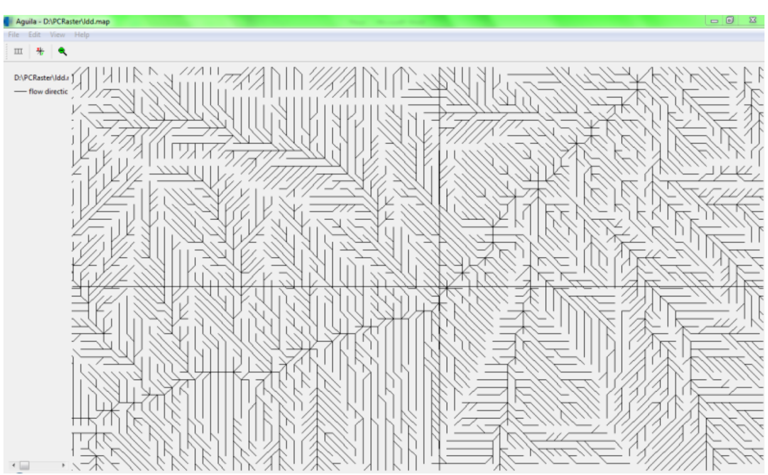
4. Data Processing

We have used Digital Surface Model (DSM). It means that this DEM already represents unknown amount of water in river beds. If we put maximum water discharge above the already existed water surface it would cause a big error. That's why we decided to use a little trick. The minimal discharge from maximum discharges were considered as the water that already exists in DTM. And the water difference between minimum from maximums and yearly maximum discharge were considered as water that causes flood/flashflood and was call "diffQ". The same was done for water level and "diffH" was created. "diffQ" and "diffH" were used to calculate return periods for 10, 50 and 100 years RP.
"diffH10", "diffH50" and "diffH100" point data was interpolated to 100m pixel size raster, but about this interpolation we will discuss a bit later.
PCRaster script was used in order to determine the height above the river from DTM. It determines the location of the main river based on the stream order of the water courses. Then the height above river for each location in the study area is computed by forcing the catchments to have their mouths at the location of the river. In a final step the map with the heights above the river is reclassified into three broad classes according to "diffH" rasters, smoothed, and non-attached clumps of the map are removed. Here is a detailed overview of this script:
create stream map "ldd.map"

*ldd.map = lddcreate(**dem(50)**.img, 1e20,1e20,1e20,1e20);*
upArea.map = accuflux(ldd.map, 1) ;
outlet.map = pit(ldd.map)   ;
upArea.map=accuflux(ldd.map, 1)   ;
so.map = streamorder(ldd.map) ;
stream.map = nominal(if(so.map>5,5)) ;

Local drain direction is a raster map with flow directions from each cell to its steepest downslope neighbor. Problem occurred because of DEM accuracy- sometimes river directions from 25k topo map didn`t match ldd.map`s directions. ArcGIS ArcHydro tool was used to burnout DEM according to 25k topo map river network layer. New, burned DEM was called "dem50.img". Than script was reruned and this operation resolved problem, ldd.map had the same direction as it is in the real world.

Figure 11: LDD.map



Creating pits at main rivers:

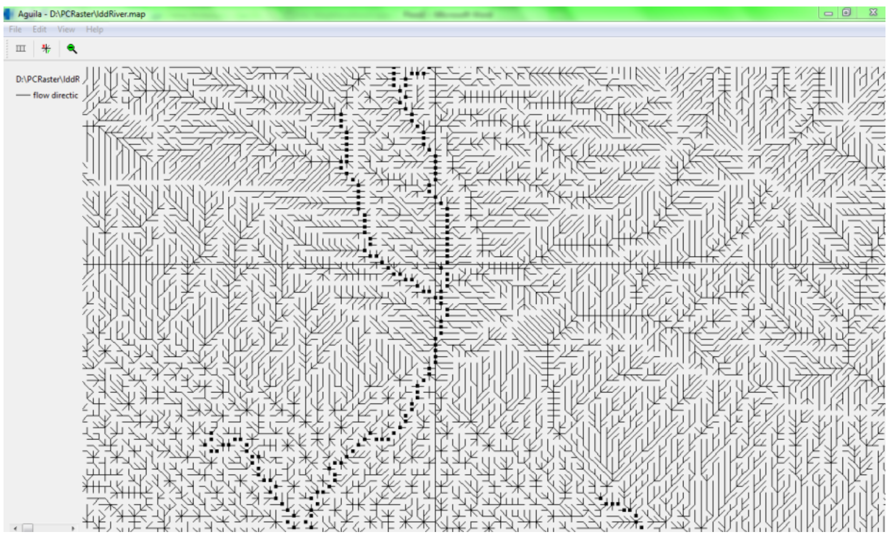
draindir.map = nominal(ldd.map) ;

newdraindir.map = cover(stream.map, draindir.map);

lddRiver.map=lddrepair(ldd(newdraindir.map))   ;

This step creates an unique value for each pit cell

Figure 12: lddriver.map



Calculating height of river for each sub catchment

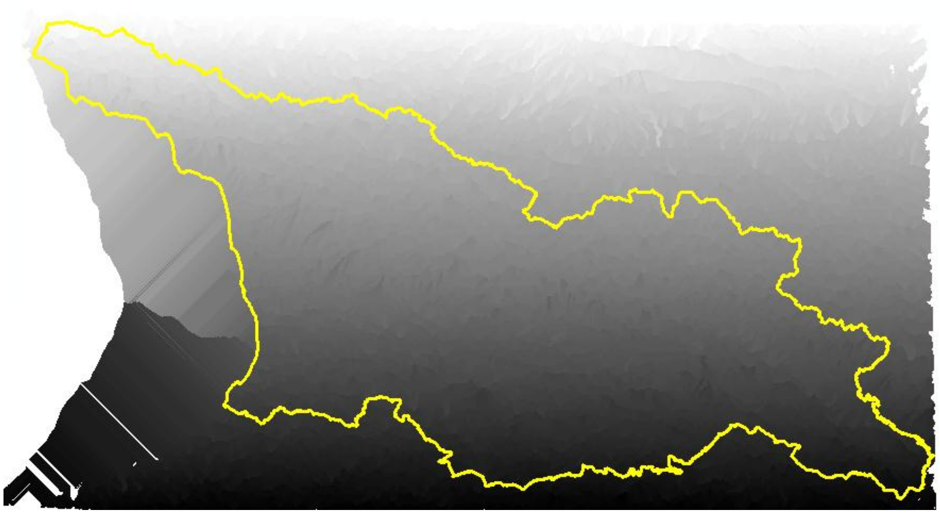
Determine catchment area for all pits at the location of the main river

riverID.map = uniqueid(boolean(stream.map));

IDnominal.map = nominal(riverID.map);

localCatchments.map = catchment(lddRiver.map, IDnominal.map);

Figure 13: Local catchments.map



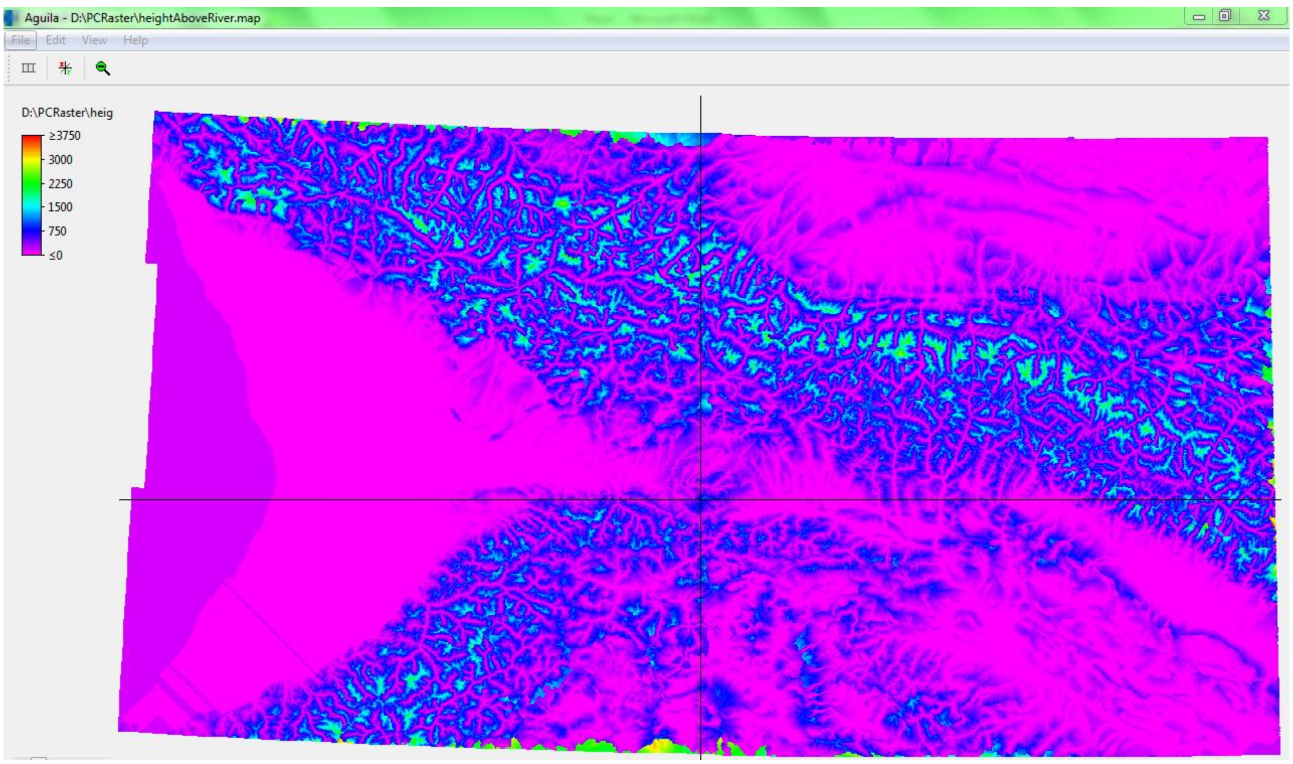
calculate local height above the river

localRiverHeight.map = areaminimum(dem.img,localCatchments.map);

heightAboveRiver.map= dem.img-localRiverHeight.map;

DEM was used in this part of script once again. But for previous case we have used DEM that was burned out -50m below stream lines in order to guarantee that LDD map would have correct stream directions. But now as far as we want to find difference between surface (DEM) and localriverheight.map, burned DEM was replaced by the original one.

Figure 14: HeightAboveRiver.map

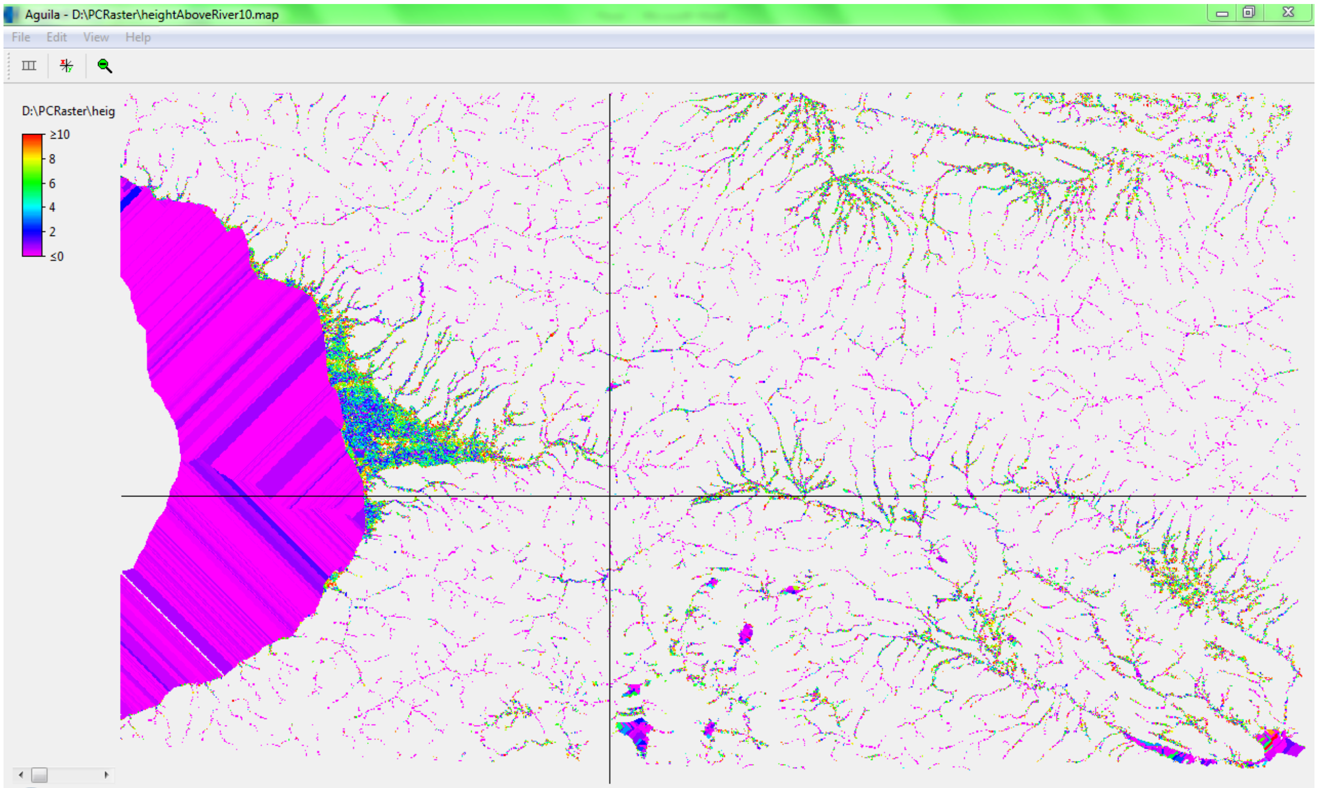


Mask out areas with height above the river of more than 10 m

heightAboveRiver10.map = if(heightAboveRiver.map lt 10, heightAboveRiver.map);

According to 100 years RP, maximum water level height is 881 cm (r. Abasha, post Sagvazao). That’s why we masked only the areas within 10 m height above river.

Figure 15: HeightAboveRiver10.map



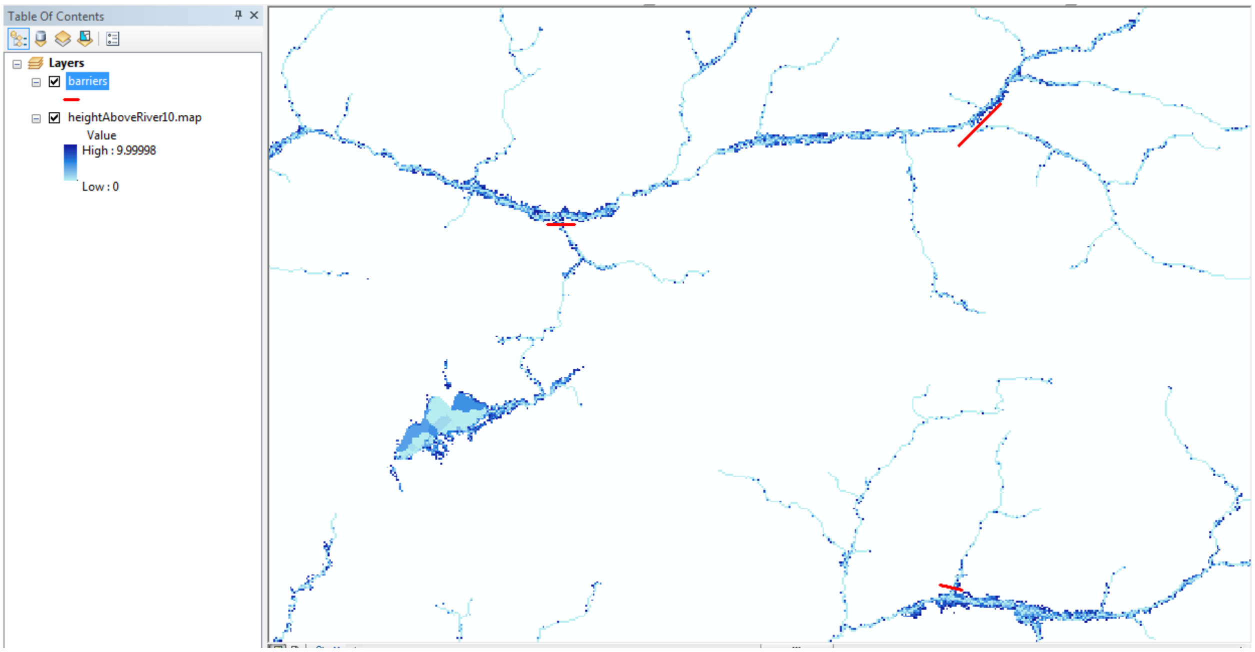
Create classified map for flood susceptibility, smooth, and mask
diff*.img are based on IDW interpolated maps

```
har.map = heightAboveRiver10.map;
extent100.map = cover(if(har.map < diff100.img/100, 100),1000)    ;
extent50.map =  cover(if(har.map < diff50.img /100, 50),1000)    ;
extent10.map =  cover(if(har.map < diff10.img /100, 10), 1000)    ;
extent0.map = cover(if(boolean(stream.map),10,1000),1000);

floodRP_t.map = min(extent0.map, extent10.map, extent50.map, extent100.map);
floodRP.map = if(floodRP_t.map < 500, floodRP_t.map);

floodRPSmooth.map = if(floodRP.map > 0, windowmajority(floodRP.map, 300));
maskClass.map = if(boolean(floodRP.map), floodRPSmooth.map);
```

It was necessary to interpolate diffH10, diffH50 and diffH100 point data, but there was a huge risk to blend data from several rivers to each other, while testing it showed that there was an influence of different rivers` data to each other. That’s why we created barrier lines and used it for Inverse Distant Weighting (IDW) interpolation. Result wasn`t satisfying, because there were still places left with “foreign” influence areas. Solution of this problem was heightaboveriver10.map. This raster represents areas which are above river, but no more than 10 meters height. We have used it as a mask layer during

IDW interpolation. So this was specific barrier. Another barriers were lines that we created near river estuaries.

Figure 16: Barrier1- red "barrier" lines; Barrier2- Heightaboveriver10.map area



So diffH10, diffH50 and diffH100 point data were interpolated and raster layers been created. But these rasters` extend is the same as har.map (former heightaboveriver10.map) has. It still doesn`t represent inundated areas for 10, 50 and 100 years RP. Above mentioned part of script computes extends for those 3 periods: Areas from har.map that have less than diff100.img values were marked as inundated area (It will be inundated at least once in 100years period) and etc.

And the final step is to delete small areas due to errors in DEM

```
clumps.map = clump(boolean(if(maskClass.map lt 1000, 1)))   ;
clumparea.map = areaarea(clumps.map);
RP.map = if(clumparea.map > 200000, maskClass.map);
RPGeorgia.map = scalar(RP.map) * scalar(clone.img);
```

Here is a whole script[8]:

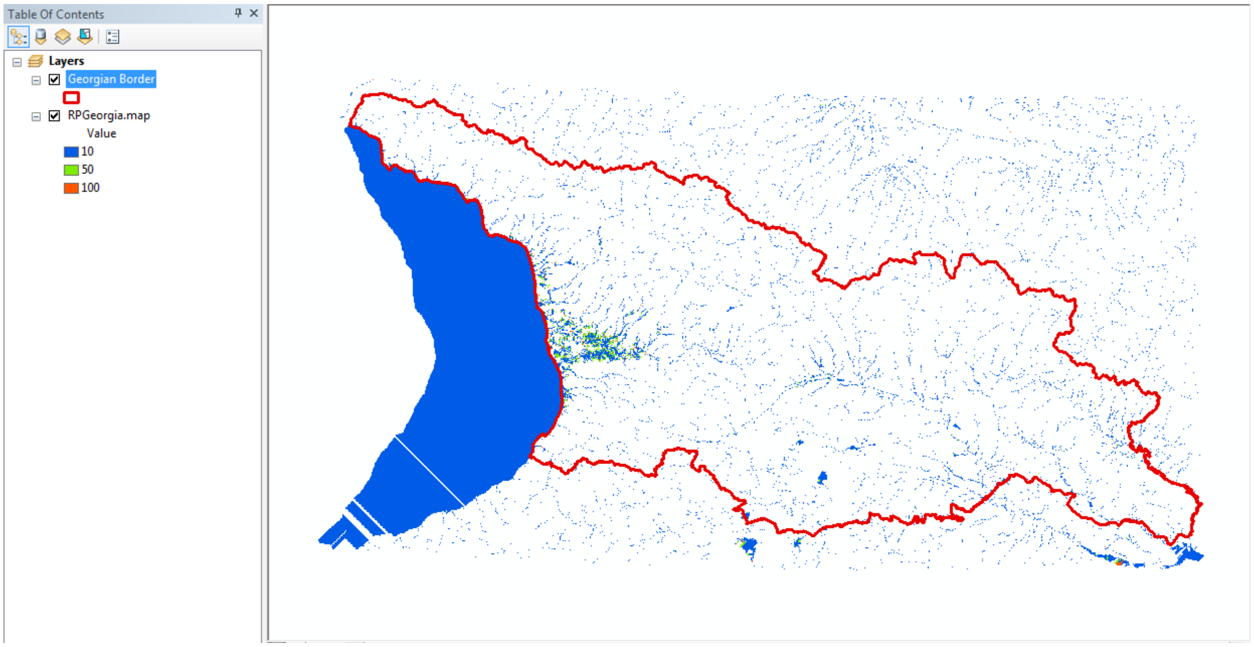
```
# create stream map
ldd.map = lddcreate(dem50.img, 1e20,1e20,1e20,1e20);
upArea.map = accuflux(ldd.map, 1)  ;
outlet.map = pit(ldd.map)         ;
upArea.map=accuflux(ldd.map, 1)          ;
so.map = streamorder(ldd.map) ;
```

[8] Script was composed by Menno Straatsma, UT-ITC, UNU school for disaster management, 2011

```
stream.map = nominal(if(so.map>5,5))  ;

# creating pits at main rivers
draindir.map = nominal(ldd.map)  ;
newdraindir.map = cover(stream.map, draindir.map);
lddRiver.map=lddrepair(ldd(newdraindir.map))   ;

# calculating height of river for each subcatchment
 # determine catchment area for all pits at the location of the main river.
 riverID.map = uniqueid(boolean(stream.map));
 IDnominal.map = nominal(riverID.map);
 localCatchments.map = catchment(lddRiver.map, IDnominal.map);

 # calculate local height above the river
 localRiverHeight.map = areaminimum(dem.img,localCatchments.map);
 heightAboveRiver.map= dem.img-localRiverHeight.map     ;

 # mask out areas with height above the river of more than 10 m
 heightAboveRiver10.map = if(heightAboveRiver.map lt 10, heightAboveRiver.map);


# create classified map for flood susceptibility, smooth, and mask
# diff*.img are based on IDW interpolated maps using IDW and polyline boundaries
har.map = heightAboveRiver10.map;
extent100.map = cover(if(har.map < diff100.img/100, 100),1000)    ;
extent50.map =  cover(if(har.map < diff50.img /100, 50),1000)     ;
extent10.map =  cover(if(har.map < diff10.img /100, 10), 1000)     ;
extent0.map = cover(if(boolean(stream.map),10,1000),1000);

floodRP_t.map = min(extent0.map, extent10.map, extent50.map, extent100.map);
floodRP.map = if(floodRP_t.map < 500, floodRP_t.map);

floodRPSmooth.map = if(floodRP.map > 0, windowmajority(floodRP.map, 300));
maskClass.map = if(boolean(floodRP.map), floodRPSmooth.map);

# delete small areas due to errors in DEM
clumps.map = clump(boolean(if(maskClass.map lt 1000, 1)))   ;
clumparea.map = areaarea(clumps.map);
RP.map = if(clumparea.map > 200000, maskClass.map);
RPGeorgia.map = scalar(RP.map) * scalar(clone.img);
```

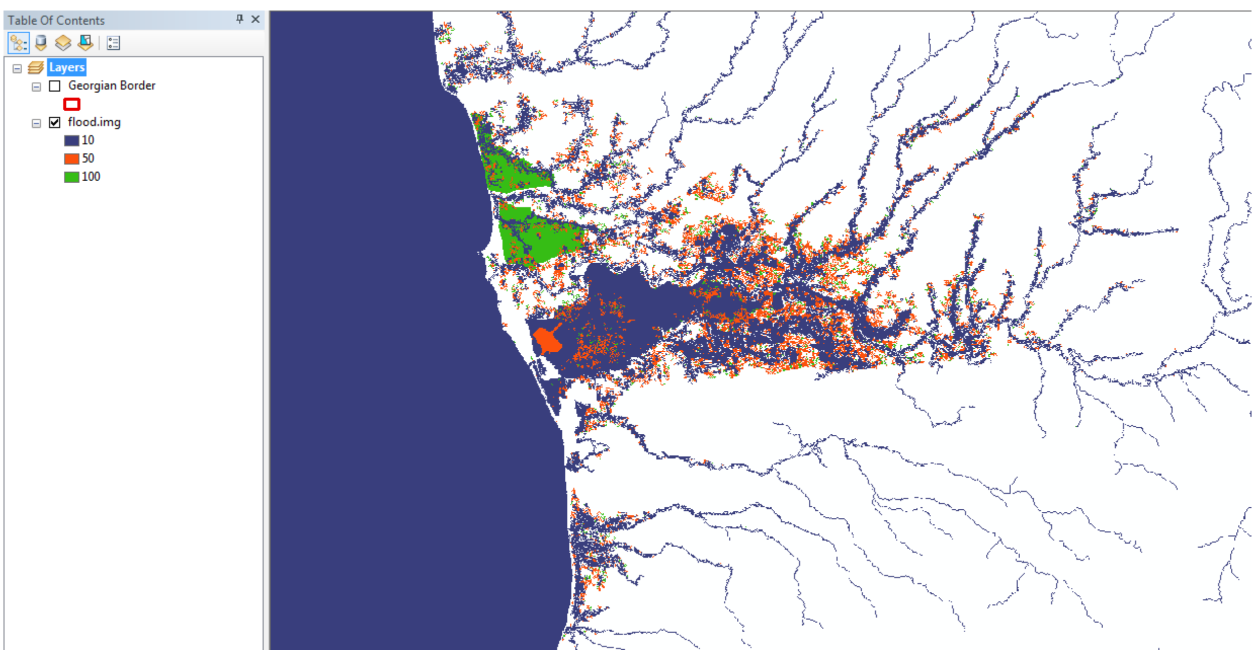
And the result is:

Figure 17: Classified inundated areas calculated by PCRaster script



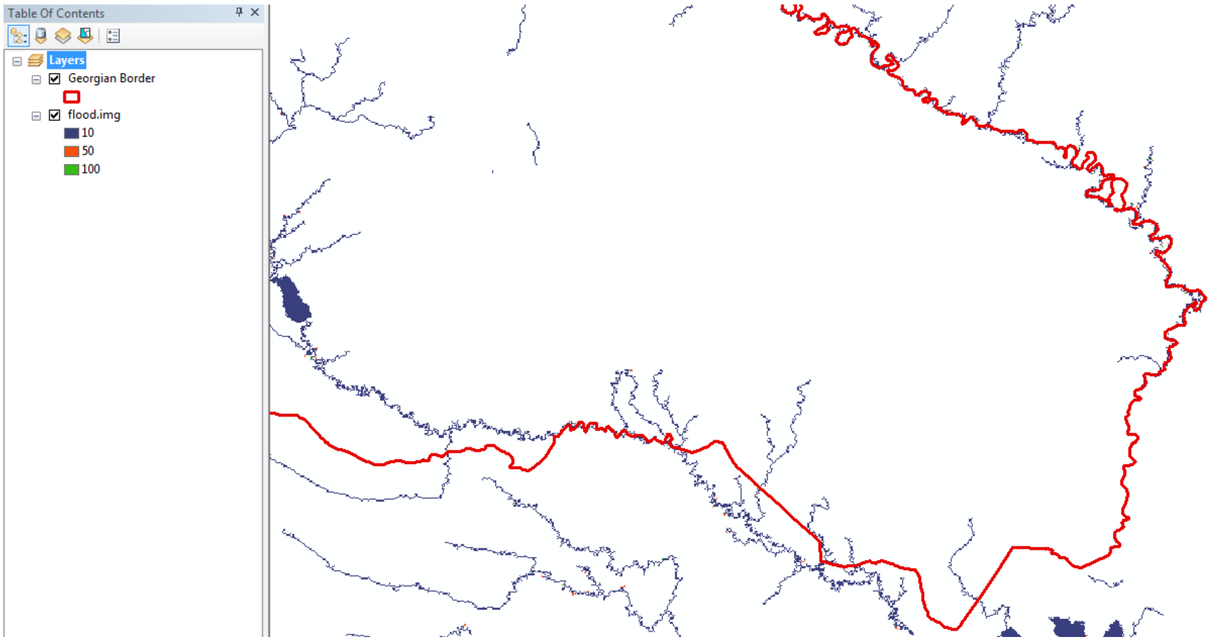
As far as we have DSM it had an influence on inundated areas results. For example Kolkheti lowland where wetland plants are grown were not inundated because of surface height produced by wetland plants. We have used Bing Maps Areal Images and those area shapes were added to inundated area for 100 years RP. The same kind areas nearby Rioni were manually “inundated”, but in this case RP was 10 years.

Figure 18: Manually corrected Kolkheti lowand



Another correction was done for the most south-eastern part of Georgia. Those areas are the driest places in Georgia. Annual average precipitation is 200-300mm[9]. There is no permanent streams or rivers, but according to our results some of these areas were inundated. That's why we have manually deleted inundation here.

Figure 19: Manually corrected semi-arid region of Georgia



According to our personal experience and also local population, areas that are between Lagodekhi and Sighnaghi Municipalities (Kakheti Region) are being inundated almost every year by river Alazani. As far as floodplain forest is presented there DSM gave us non-inundated areas there. As representative of local government told us sometimes water reaches to village Heretiskari.

[9] Climate catalog book of USSR

Figure 20: R. Alazani, floodplain and v. Heretiskari

That's why we added floodplain forest area till the village Heretiskari and added it to inundation map, RP is 10 years.

As far as main reasons of such big floods are rivers flowing from north (Kabali, Areshi, etc.) western border of inundated area was ended near the estuary of those rivers and Alazani. Eastern border is the same as Georgian State border, because our maps are done just for the territory of Georgia.

Figure 21: Manually added inundated area

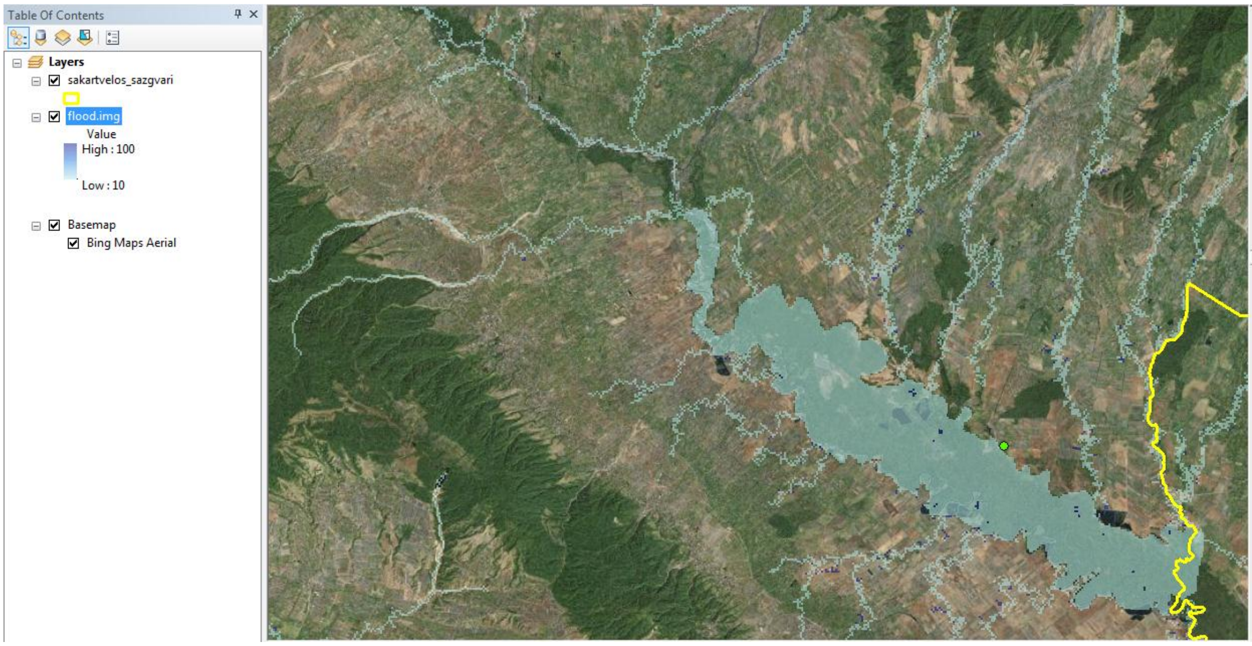
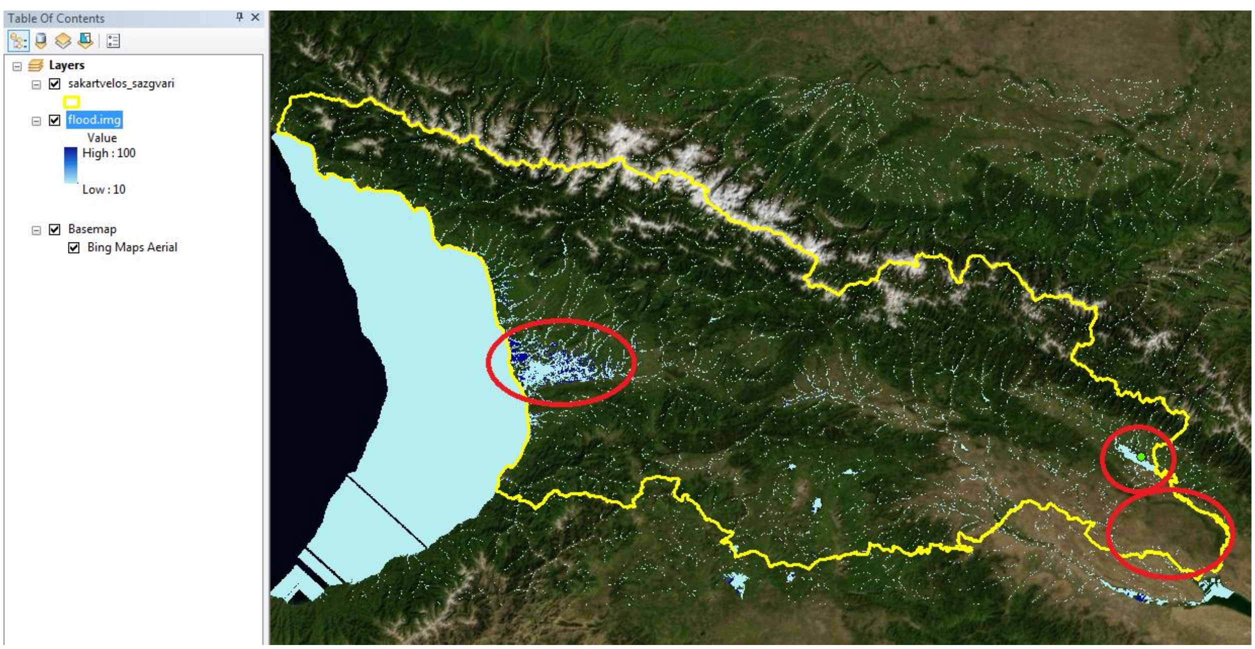


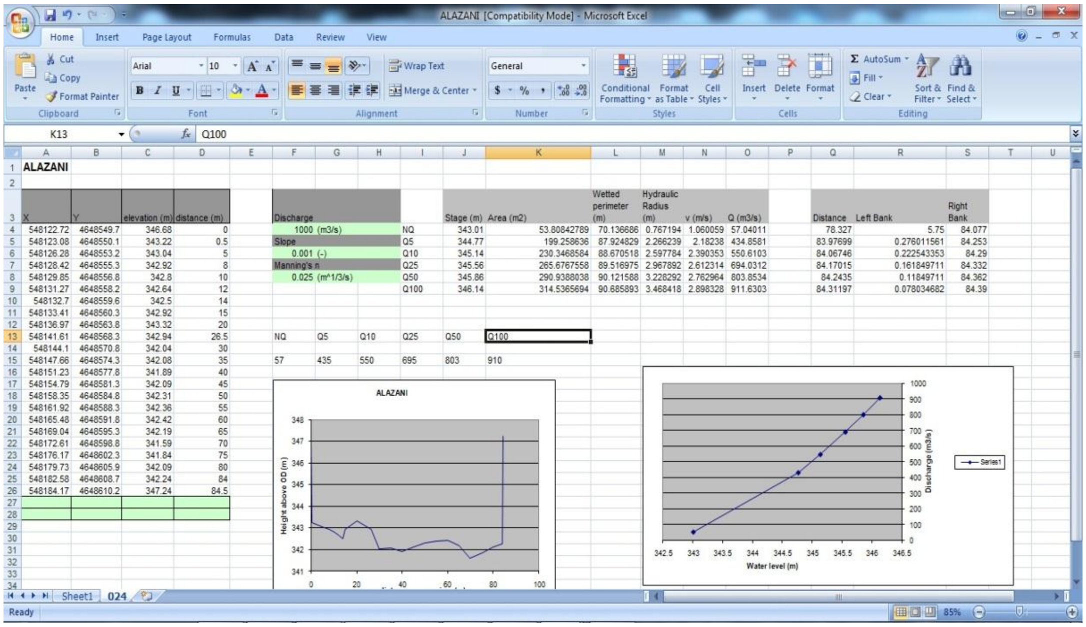
Figure 22: Manually corrected areas



5. Validation

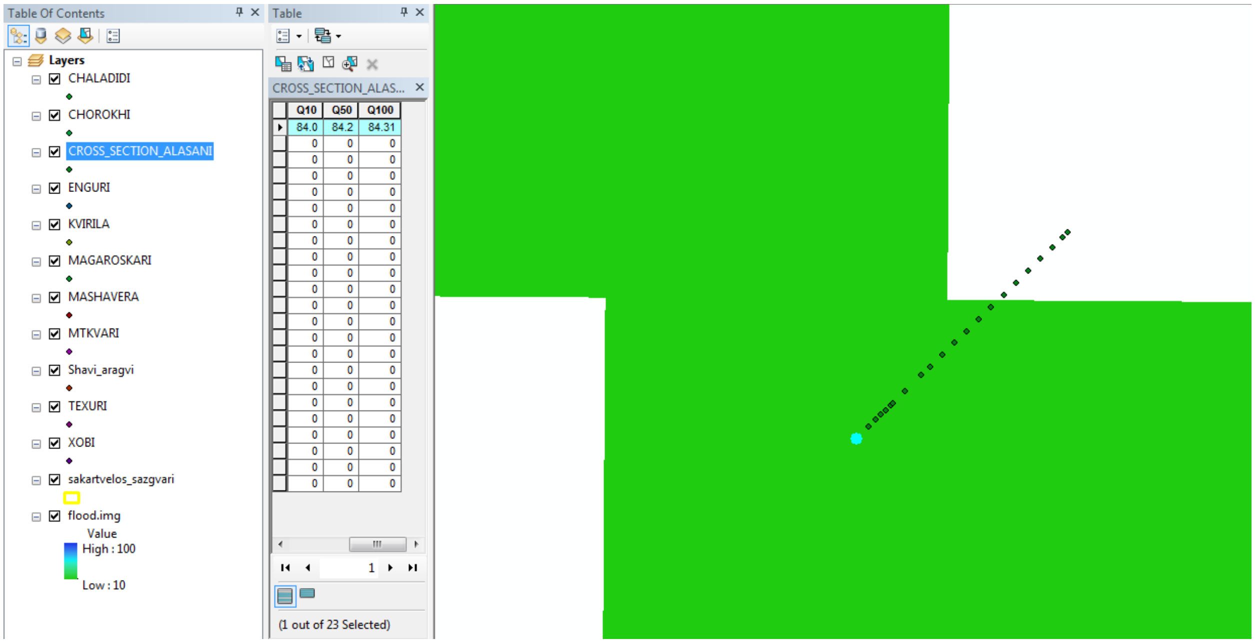
5.1. Validation by Cross Sections

There was a problem with these cross sections. They had just one fixed point for each cross-section. We have calculated coordinates for whole cross sections and attached them in ArcGIS. From the topographical map and Digital Elevation Model we have calculated local slope for each cross section. Next stage was calculation of cross sectional parameters, such as: area, wetted perimeter, hydraulic radius, left bank, right bank and distance. We have calculated flood width for 10, 50 and 100 year probability. This calculation was made by Excel extension Hydrotoolbox.



This data was used to validate inundation map. Mainly cross section RP width was very close to inundation map.

Figure 23: Cross section maximum width (for 100 years RP) is about 85m and is spread on 2 neighboring pixel of inundation



5.2. Validation by Historical Data from Media

Unfortunately we could create historical flood/flashflood layer just on the level of communities, but even this level was more or less useful for validation our results

Figure 24: General view. yellow- Historical data from media; Blue- inundation map.

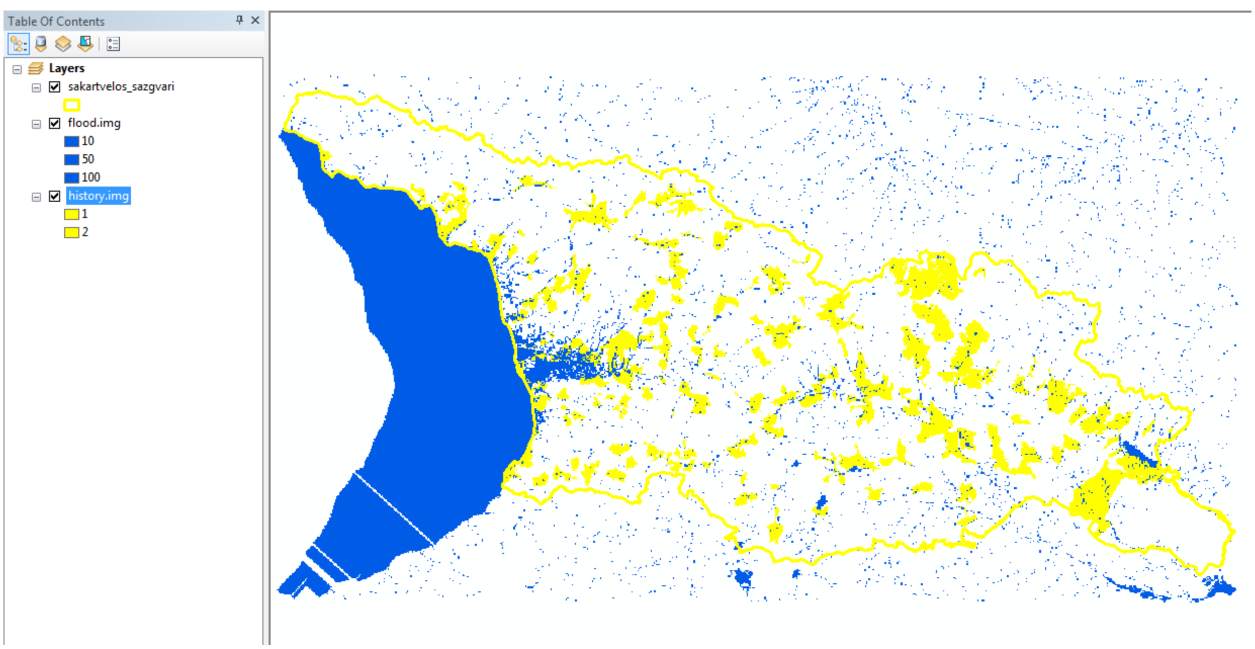


Figure 25: More detailed view #1

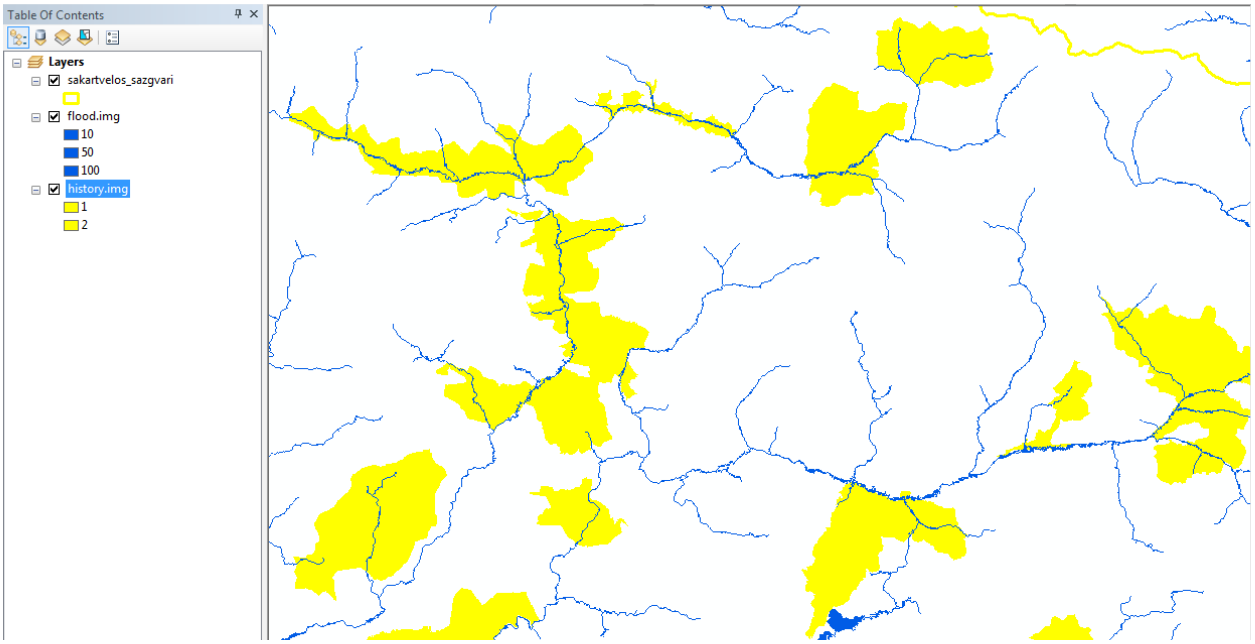
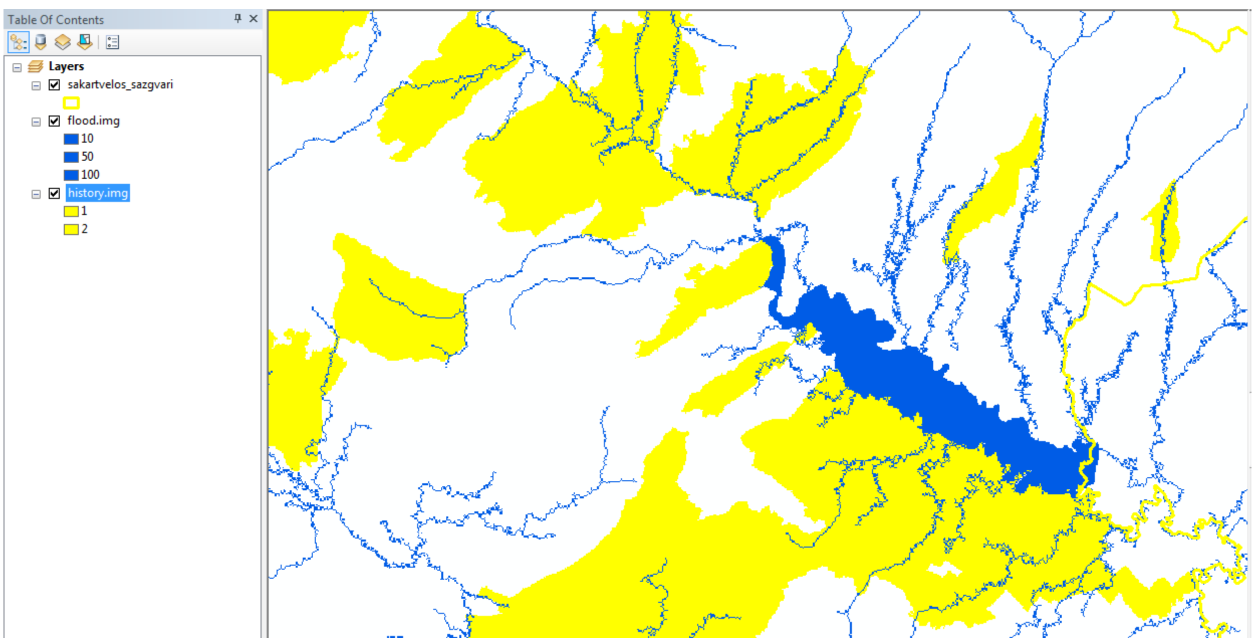


Figure 26: More detailed view #2



As we see results are not bad.

6. Problems

There were plenty of problems. The main problem was that we had no many necessary information about hydrological characteristics. On the other hand, the data we could get was very old and sometimes were not reflecting reality. We had only several cross sections and we only managed to use them for validation purposes. We have used middle resolution DSM and this was another problem. We would like to use DTM derived from 50k topo map, but quality check revealed huge errors there (error source was digitizing).

The main point is that our target was to create classified inundation map for whole Georgia (~70 000km^2). That's why we had to sacrifice pixel size (it was increased from ~28m to 100m) and as a result – sometimes quality.

Despite such a big problems, we managed to preserve ties to real situation and we can say that our final inundation map is as good as it can be for national scale (also regarding data we had).