Population Effected by the Storm Surge of the Great Sendai Earthquake; March 11 2011

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Background:

On March 11, 2011 a magnitude 9.0 earthquake hit the northwestern coast of Japan, resulting in a major tsunami. This was the most powerful known earthquake to have ever hit Japan. The average storm surge was 10 meters, and caused complete devastation and displacement throughout Japan.

Goal:

The goal of this project is to analyze the population affected by the average storm surge (10 meters) in the coastal Miyagino and Wakabayshi wards of Sendai, Miyagi prefecture of Japan following the Great Sendai Earthquake.

A final map is presented showing the areas that were affected by the 10 meter storm surge, and the areas that remained unaffected by the storm surge, as well as a chart showing the approximated population affected in each of the wards. This map is accompanied by two reference maps (1) to show the location of the Miyagi Prefecture in Japan and (2) the location of the Miyagino and Wakabayshi wards in Sendai, Miyagi Japan.

Data Collection:

Data used in this project came from the following sources:

- Spatial data of Japan: http://www.diva-gis.org/datadown
  - JPN_adm0: shapefile boundary of Japan
  - JPN_adm1: shapefile boundary of prefectures of Japan
  - JPN_adm2: shapefile boundary of cities and towns of Japan
- DEM data of Northeastern Japan:
  - http://asterweb.jpl.nasa.gov/gdem.asp
  - Created account through GDEx
  - Download from LP DAAC Global Data
- Miyagino and Wakabayshi ward image:
  - http://www.bing.com/images/search?q=wards+of+sendai+image&id=EDFA47EEB9AE444CC74A7F2C42CD1E0AB7C21D4B&FORM=IQFRBA#view=detail&id=EDFA47EEB9AE444CC74A7F2C42CD1E0AB7C21D4B&selectedIndex=0

- Population of cities in Miyagi:
  - http://www.citypopulation.de/Japan-Miyagi.html
  - Data according to 2010 census data of Japan

Data Preprocessing:

The chosen coordinate system for this project was WGS_1984_UTM_zone_54N. Data collected from the Aster data set were initially downloaded and projected in the GCS_WGS_1984 coordinate system so preprocessing was required to convert the coordinate system into UTM. Use Data management project tool to change the input coordinate system (GCS_WGS_1984) to new output coordinate system (WGS_1984_UTM_zone_54N).

The JPN_adm shapefiles were projected on the fly when imported into ArcGIS and therefore did not need to be projected.

Georeferencing was required for the imported image of the Miyagino and Wakabayshi wards of Sendai (wards.png) to JPN_adm0 shapefile.

ArcGIS Processing:

These are the following steps that I took to analyze the data imported into ArcGIS to create my final map and table:

1. Add all data to ArcMap
2. Create new shapefile of the Miyagi Prefecture
3. Create a new shapefile for cities of Miyagi Prefecture
4. Create a mask of the DEM to the new Miyagi Prefecture
5. Create a hillshade of the new DEM of the Miyagi Prefecture
6. Digitize Miyagino and Wakabayshi wards of Sendai as polygons
7. Export data of the new Miyagino and Wakabayshi polygon shapefiles
8. Add population, and area data to attribute table of “m_city_clp”
9. Create 10 meter contour value within Miyagi Prefecture
10. Create 10 meter constant raster for Miyagino and Wakabayashi wards using the “constant raster tool”
11. Use cut fill tool to show areas affected by 10 meter storm surge
12. Use “feature to point tool” to create center points for population of each ward
13. Calculations of population affected

1. Add all data to ArcMap

a. Open blank ArcMap document
b. Connect to project folder (GIS_Final_Project)
c. Add data:
    i. JPN_adm0
    ii. JPN_adm1
    iii. JPN_adm2
    iv. Miya_ras

2. Create new shapefile of Miyagi Prefecture

a. Open attribute table of JPN_adm2 and select Miyagi
b. Export data to create a separate Miyagi shapefile (yellow polygon below is Sendai)

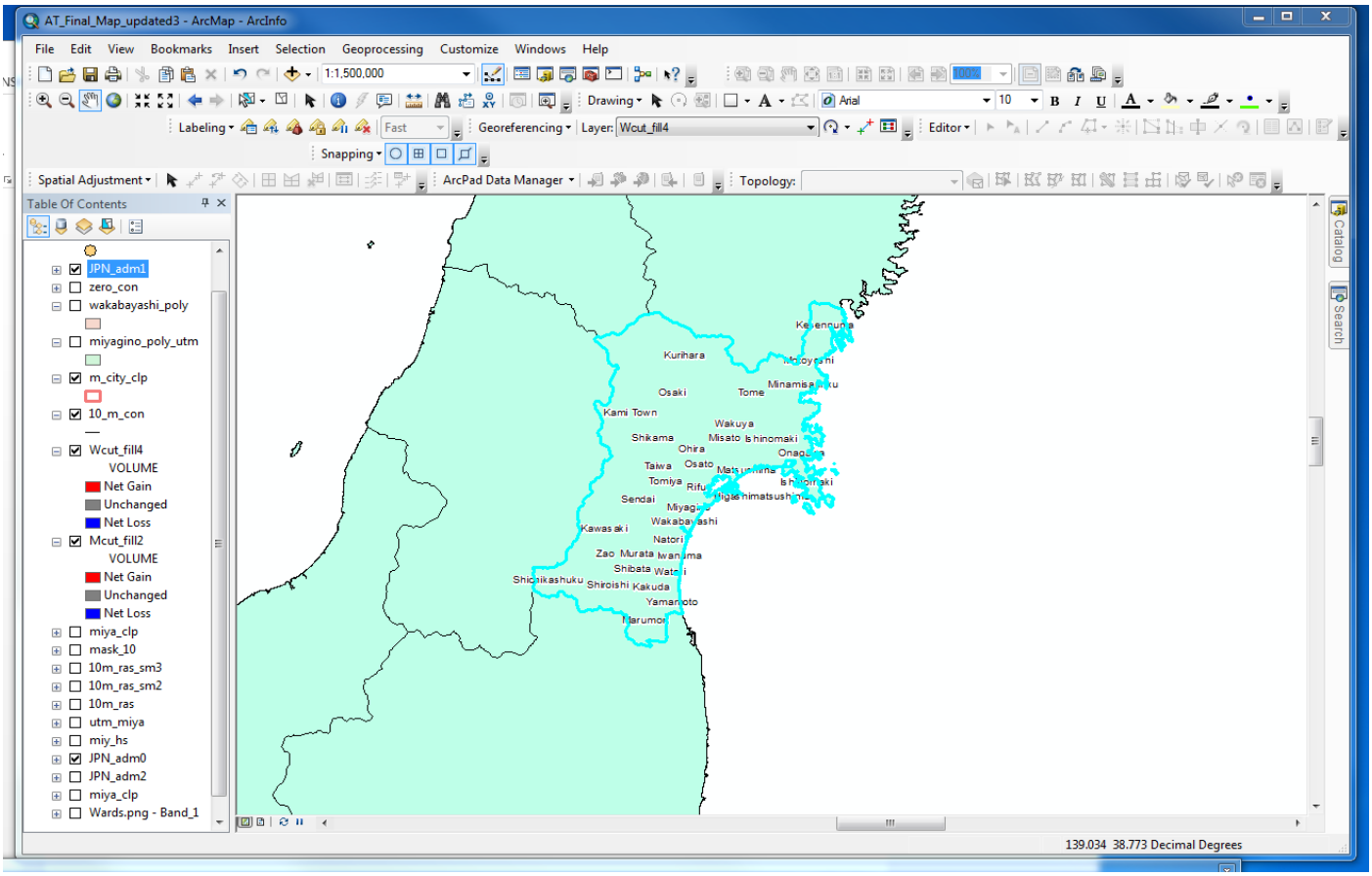
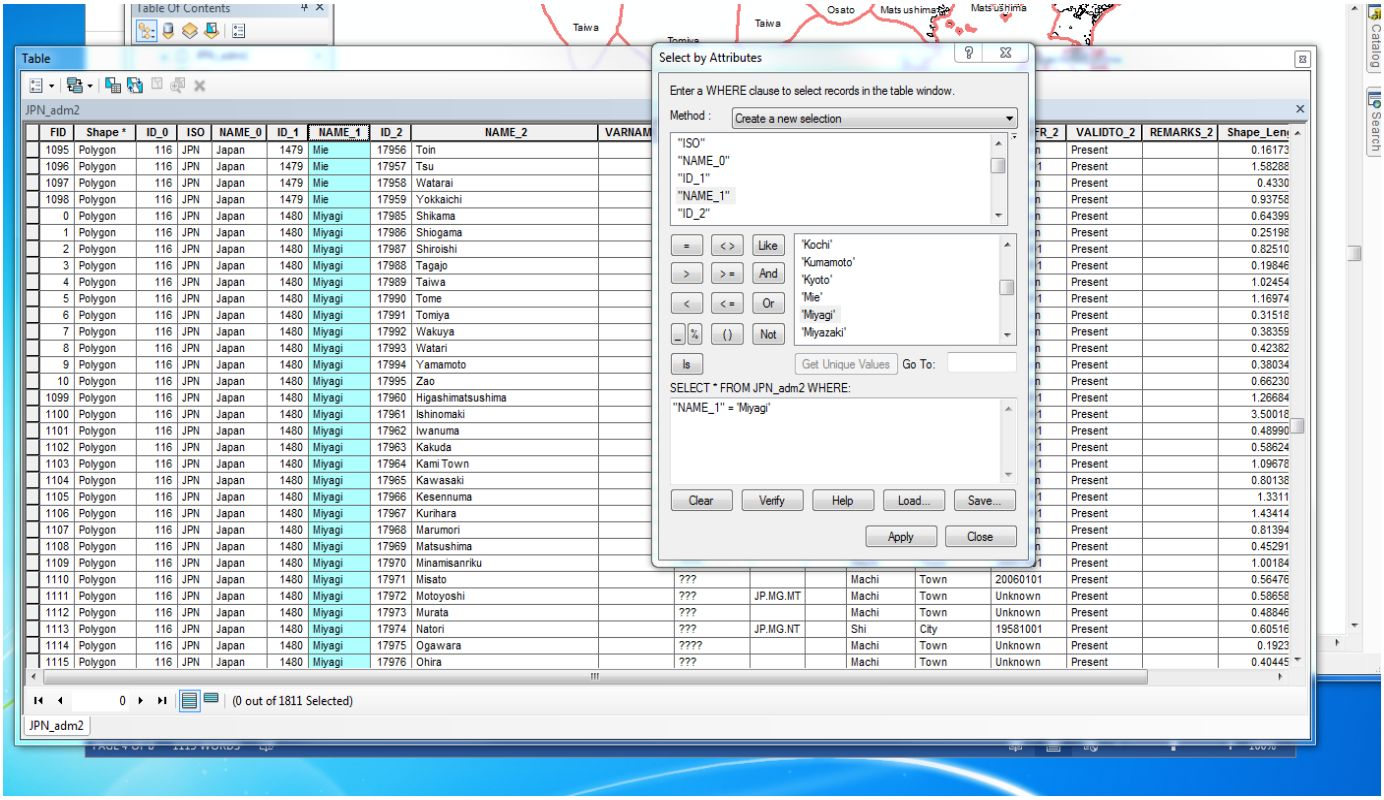


Figure 1: Miyagi Prefecture selected from attribute table

3. Create a new shapefile for cities of Miyagi Prefecture

a. Open JNP_adm2 attribute table and select all cities and towns within the Miyagi Prefecture



FID	Shape *	ID_0	ISO	NAME_0	ID_1	NAME_1	ID_2	NAME_2	VARNAM						FR_2	VALIDTO_2	REMARKS_2	Shape_Len
1095	Polygon	116	JPN	Japan	1479	Mie	17956	Toin								Present		0.16173
1096	Polygon	116	JPN	Japan	1479	Mie	17957	Tsu								Present		1.58288
1097	Polygon	116	JPN	Japan	1479	Mie	17958	Watarai								Present		0.4330
1098	Polygon	116	JPN	Japan	1479	Mie	17959	Yokkaichi								Present		0.93758
0	Polygon	116	JPN	Japan	1480	Miyagi	17985	Shikama								Present		0.64399
1	Polygon	116	JPN	Japan	1480	Miyagi	17986	Shiogama								Present		0.25198
2	Polygon	116	JPN	Japan	1480	Miyagi	17987	Shiroishi								Present		0.82510
3	Polygon	116	JPN	Japan	1480	Miyagi	17988	Tagajo								Present		0.19846
4	Polygon	116	JPN	Japan	1480	Miyagi	17989	Taiwa								Present		1.02454
5	Polygon	116	JPN	Japan	1480	Miyagi	17990	Tome								Present		1.16974
6	Polygon	116	JPN	Japan	1480	Miyagi	17991	Tomiya								Present		0.31518
7	Polygon	116	JPN	Japan	1480	Miyagi	17992	Wakuya								Present		0.38359
8	Polygon	116	JPN	Japan	1480	Miyagi	17993	Watari								Present		0.42382
9	Polygon	116	JPN	Japan	1480	Miyagi	17994	Yamamoto								Present		0.38034
10	Polygon	116	JPN	Japan	1480	Miyagi	17995	Zao								Present		0.66230
1099	Polygon	116	JPN	Japan	1480	Miyagi	17960	Higashimatsushima								Present		1.26684
1100	Polygon	116	JPN	Japan	1480	Miyagi	17961	Ishinomaki								Present		3.50018
1101	Polygon	116	JPN	Japan	1480	Miyagi	17962	Iwanuma								Present		0.48990
1102	Polygon	116	JPN	Japan	1480	Miyagi	17963	Kakuda								Present		0.58624
1103	Polygon	116	JPN	Japan	1480	Miyagi	17964	Kami Town								Present		1.09678
1104	Polygon	116	JPN	Japan	1480	Miyagi	17965	Kawasaki								Present		0.80138
1105	Polygon	116	JPN	Japan	1480	Miyagi	17966	Kesennuma								Present		1.3311
1106	Polygon	116	JPN	Japan	1480	Miyagi	17967	Kurihara								Present		1.43414
1107	Polygon	116	JPN	Japan	1480	Miyagi	17968	Marumori								Present		0.81394
1108	Polygon	116	JPN	Japan	1480	Miyagi	17969	Matsushima								Present		0.45291
1109	Polygon	116	JPN	Japan	1480	Miyagi	17970	Minamisanriku								Present		1.00184
1110	Polygon	116	JPN	Japan	1480	Miyagi	17971	Misato		???			Machi	Town	20060101	Present		0.56476
1111	Polygon	116	JPN	Japan	1480	Miyagi	17972	Motoyoshi		???	JP.MG.MT		Machi	Town	Unknown	Present		0.58658
1112	Polygon	116	JPN	Japan	1480	Miyagi	17973	Murata		???			Machi	Town	Unknown	Present		0.48846
1113	Polygon	116	JPN	Japan	1480	Miyagi	17974	Natori		???	JP.MG.NT		Shi	City	19581001	Present		0.60516
1114	Polygon	116	JPN	Japan	1480	Miyagi	17975	Ogawara		????			Machi	Town	Unknown	Present		0.1923
1115	Polygon	116	JPN	Japan	1480	Miyagi	17976	Ohira		???			Machi	Town	Unknown	Present		0.40445

Figure 2: JNP_adm2 attribute table showing selection of all cities and towns within the Miyagi Prefecture

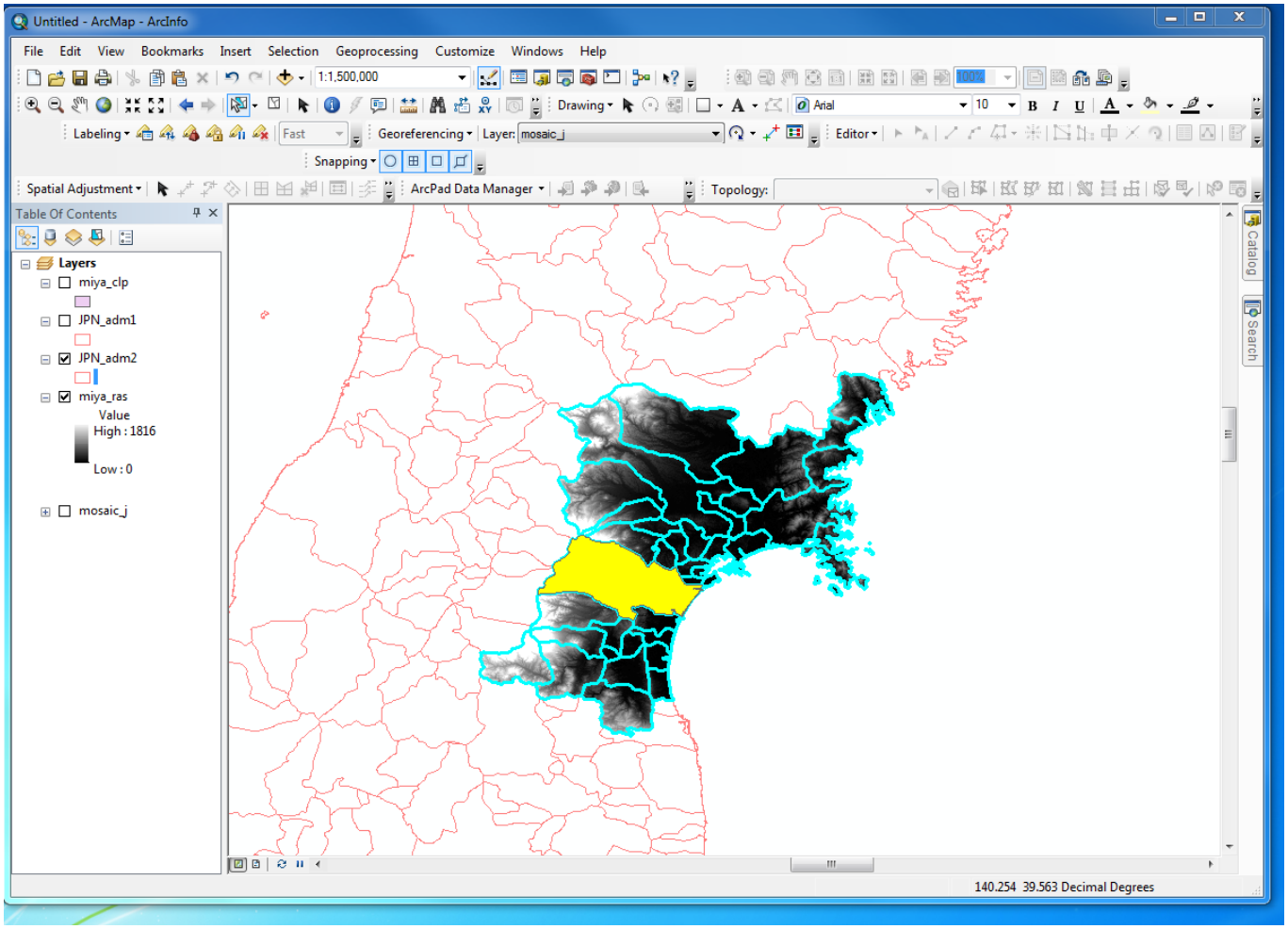


Figure 3: Cities of Miyagi selected from attribute table

i. Done by "select by attributes" → Name_1=Miyagi

b. Export data to new shapefile layer, called "m_city_clp"

4. Create a mask of the DEM to the new Miyagi Prefecture

a. Use "extract by mask" spatial analyst tool

b. Use utm_miya as a mask for the miya_ras

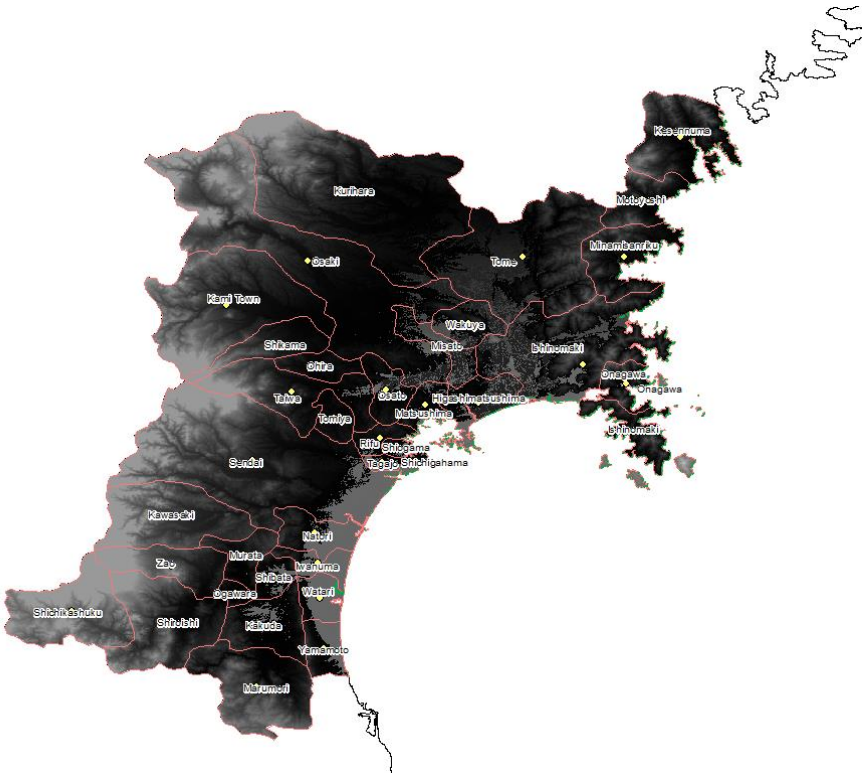


Figure 4: Mask of DEM of Miyagi Prefecture

5. Create a hillshade of the new DEM of the Miyagi Prefecture

a. Use hillshade spatial analyst tool to create a hillshade of the Miyagi Prefecture
b. Input raster is utm_miya
c. Output raster is miy_hs
d. Make transparency of utm_miya 40%

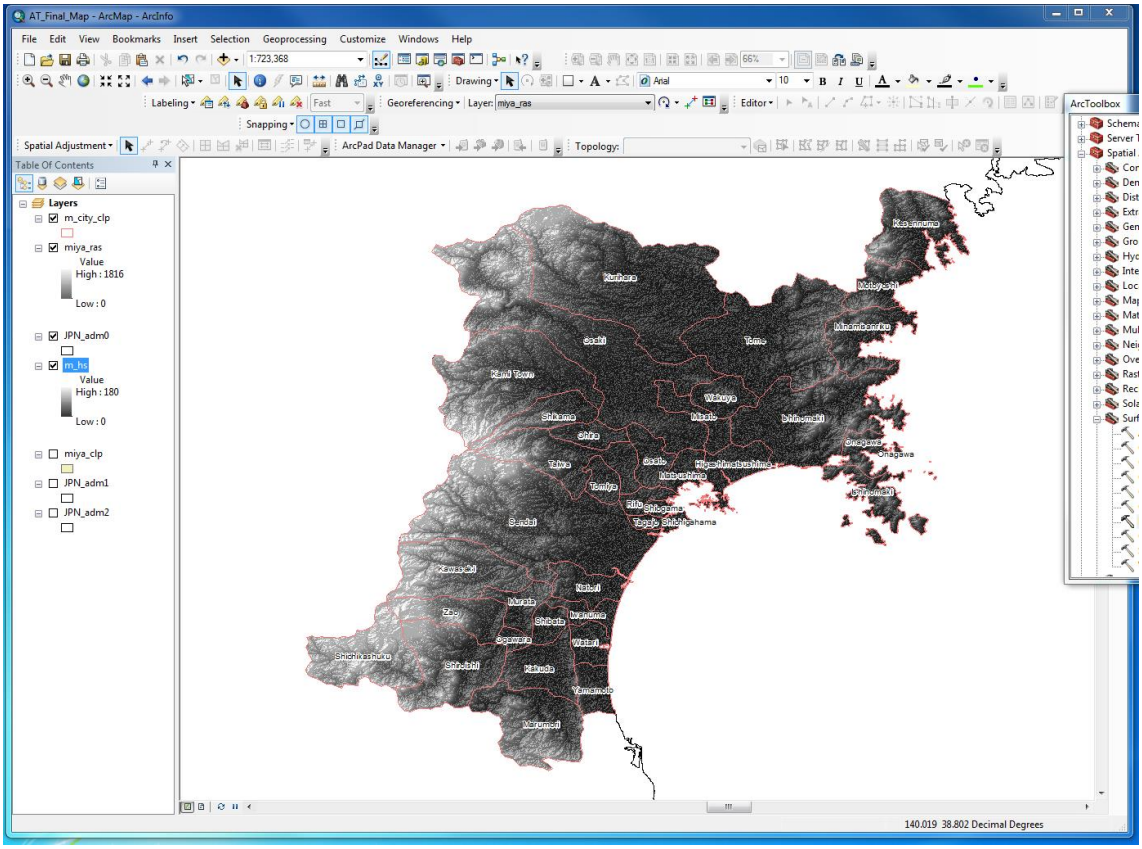


Figure 5: Hillshade of Miyagi Prefecture

6. Digitize Miyagino and Wakabayshi wards of Sendai as polygons

a. Use editing tool to create new polygons following the borders of the Miyagino and Wakabayshi wards.

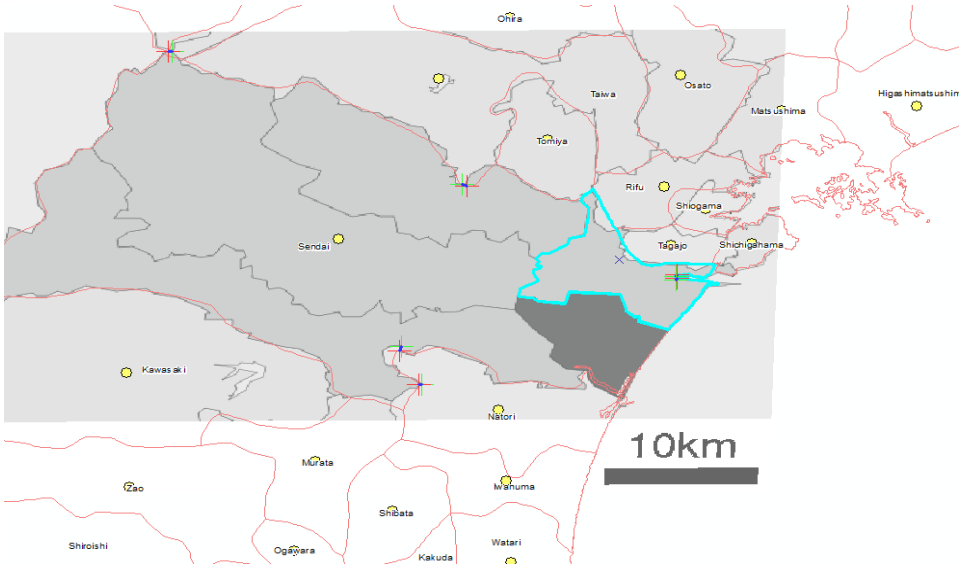


Figure 6: Overlain ward maps shown as reference for digitizing Wakabayshi and Miyagino wards

7. Export data from new digitized polygons to make two individual polygon shapefiles

a. Shapefiles saved as wakabayashi_poly and miyagnio_poly_utm

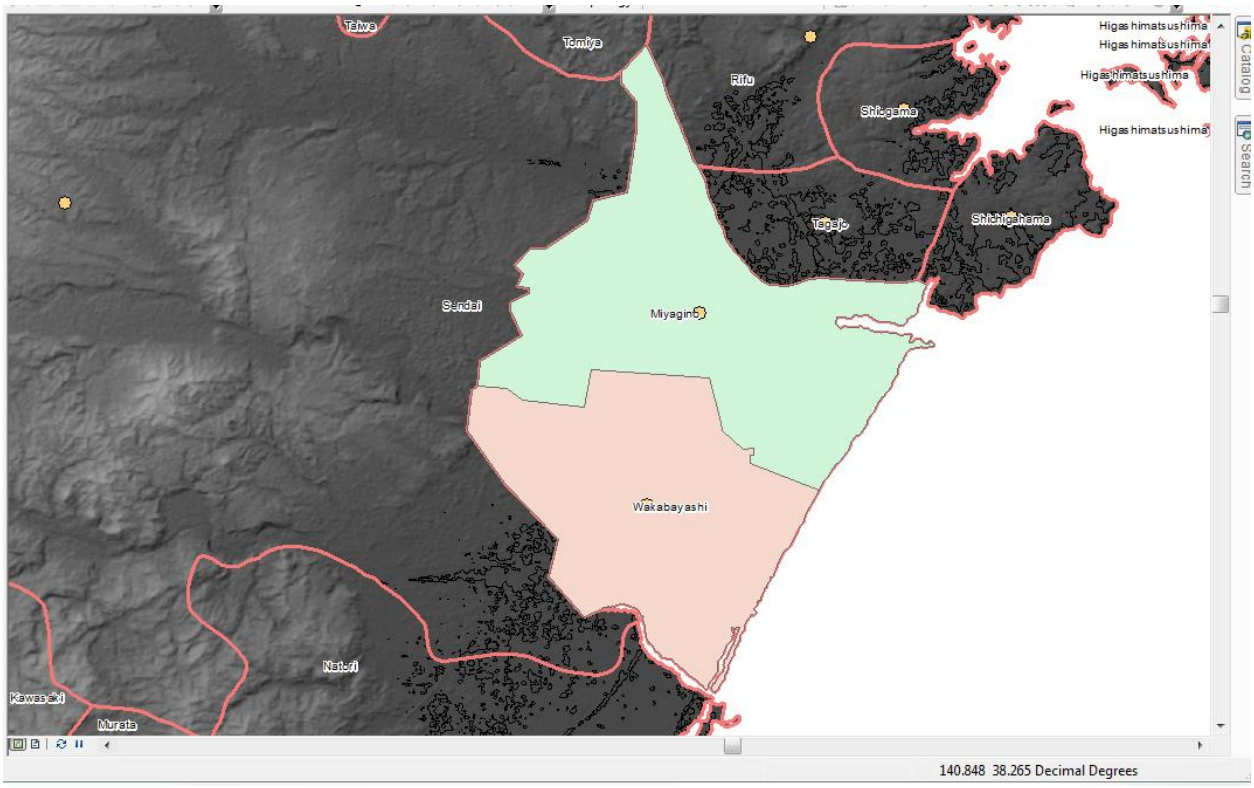


Figure 7: Exported Wakabayshi and Miyagino wards

8. Add population, and area data to attribute table of "m_city_clp"

a. Create new fields in the "m_city_clp" attribute table
   i. Drop down "Table option menu" in "m_city_clp" attribute table
   ii. Select "add field"
   iii. Name "population 2010 census"
   iv. Short integer type
   v. Precision=8
   vi. Start and editing session, select "m_city_clp" to manually edit and add population values

vii. Add values for each of the cities/towns of Miyagi Prefecture and the Miyagino and Wakabayshi wards
viii. Manually add area value of both the wards (different field)

9. Create 10 meter contour with in the Miyagi Prefecture

a. Open contour tool in toolbox
b. Set input raster as “utm_miya”
c. Set output polyline features to the “10_m_con”
d. Set contour interval to 1820, because that is the highest elevation on the DEM
e. Set base contour to 10, so that contour interval will mark 10 meters

10. Create 10 meter constant raster for both the Miyagino and Wakabayashi wards using the “constant raster tool”

a. The purpose of creating a constant 10 meter raster is so that this raster can be used as the “input after raster surface” in the next step, the cut and fill tool. This constant raster will show an even plane that will divide the area above and below the constant raster as areas that area affected by the storm surge, and areas that are not affected. The final goal of this project.
b. Open “constant raster tool”
c. Make extents ”wakabayashi_poly” and “miyagino_poly_utm” for respective Wakabayshi and Miyagino wards
d. Constant value=10
e. Cell size=30
f. Name “10m_ras_sm2” (miyagino ward)
g. Name “10m_ras_sm3” (wakabayashi ward)

11. Use cut fill tool to show areas affected by 10 meter storm surge

a. The cut fill tool will create two planes (red and blue) representing the area above the 10 meter storm surge plane (blue) and the area below the 10 meter storm surge plane (red)
b. Repeat the following processes for both the Miyagino and Wakabayashi wards
c. Make input before raster surface= “utm_miya”
d. Make input after raster surface= “10m_ras_sm2” and “10m_ras_sm3” for respective Miyagino and Wakabayashi wards; these are the constant 10 meter raster’s from step 10
e. Save output as “Mcut_fill2” (for Miyagino ward) and “Wcut_fill4” (for Wakabayashi ward)
f. These two new polygons represent the areas above “net loss” and below “net gain” the 10 meter constant raster, these values also align with the 10 meter contours created earlier, showing that the “cut fill” tool correctly did its job

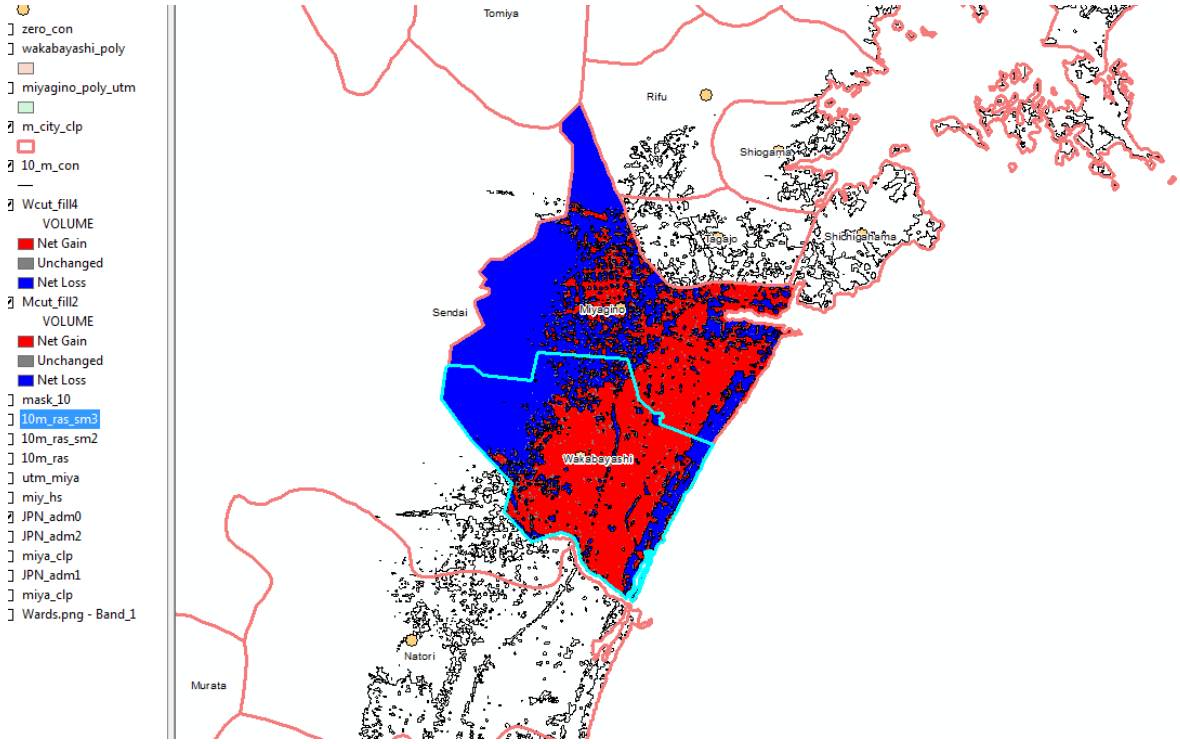


Figure 8: Effects of the cut and fill tool, showing area above and below 10 meter raster

12. Use “feature to point tool” to create center points for population of each ward

a. Use feature to point tool under data management tool
b. Input feature= “m_city_clp” shapefile
c. Name output “miya_cent” shapefile
d. Populations of each city and the two wards have now been symbolized by yellow dots in the center of each polygon
    i. Population values are present in the attribute tables

13. Calculations of population affected

a. In the final map, the red region signifies area flooded by 10 meter storm surge and the blue region signifies the areas not flooded by the 10 meter storm surge.
b. View attribute tables of both Wcut_fill4 and Mcut_fill2 polygons and organize by volume, select all values by doing query where volume<0 do statistics and will select area affected by flood.

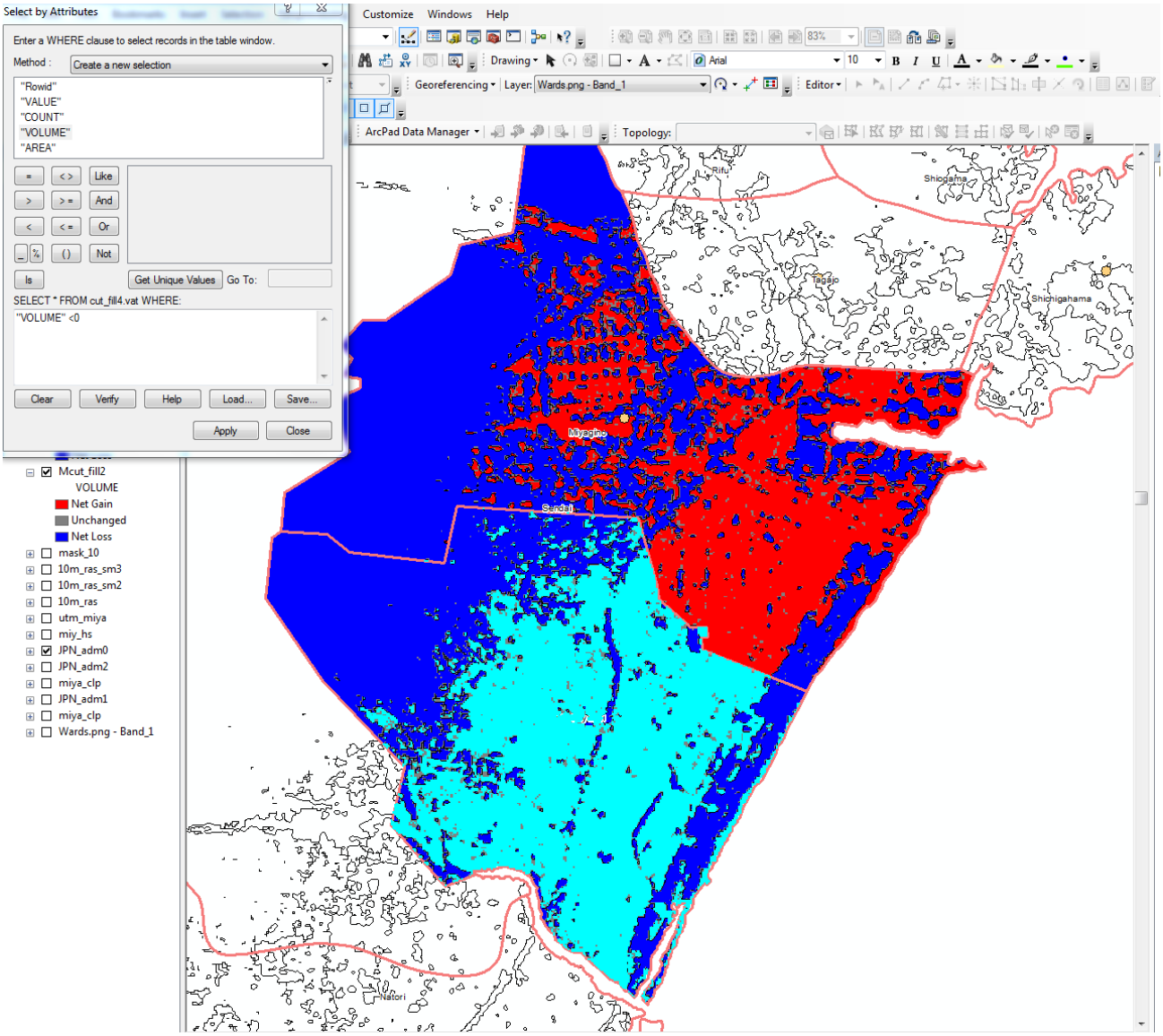
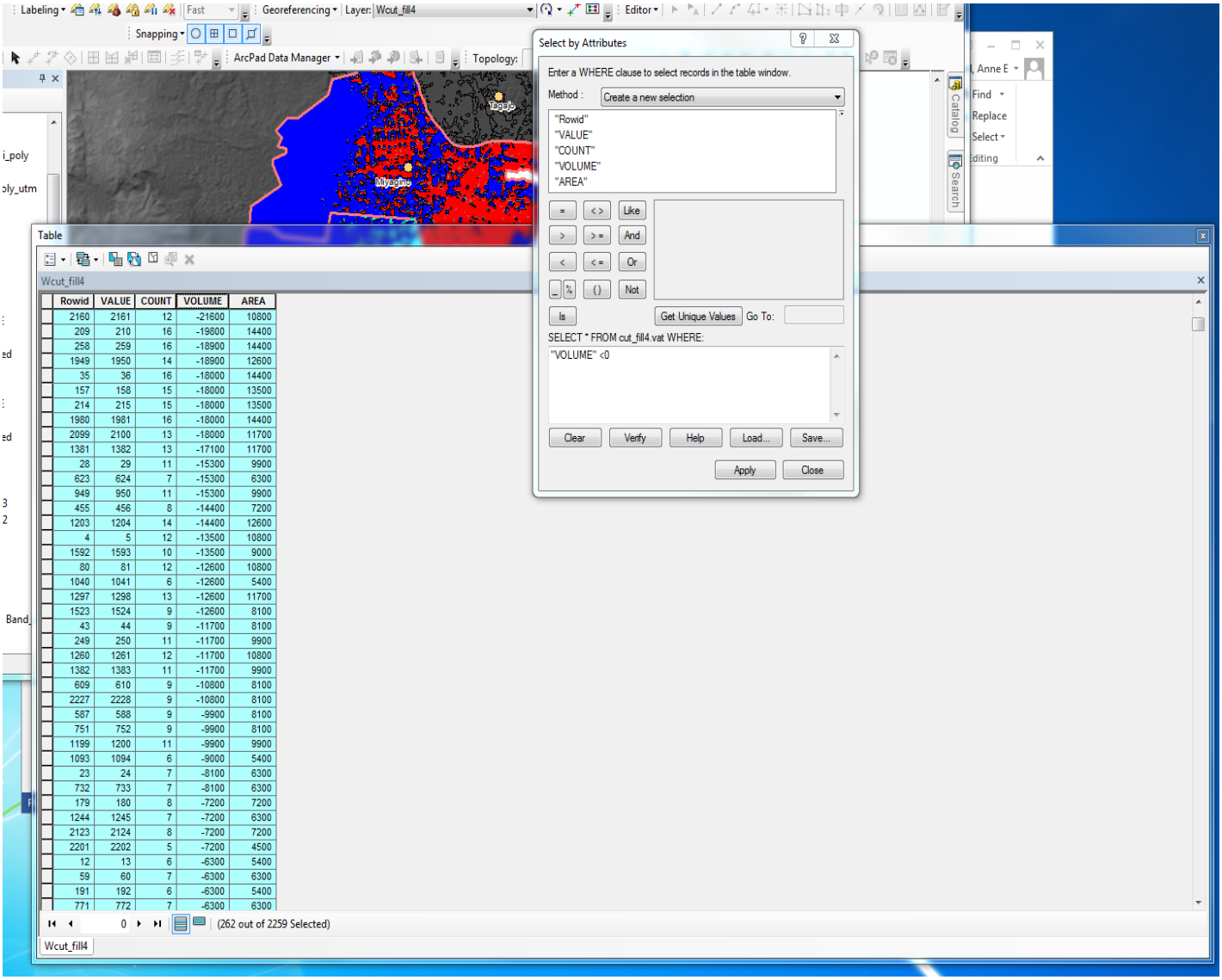


Figure 9: How to select the “Net gain” area of the cut fill



Rowid	VALUE	COUNT	VOLUME	AREA
2160	2161	12	-21600	10800
209	210	16	-19800	14400
258	259	16	-18900	14400
1949	1950	14	-18900	12600
35	36	16	-18000	14400
157	158	15	-18000	13500
214	215	15	-18000	13500
1980	1981	16	-18000	14400
2099	2100	13	-18000	11700
1381	1382	13	-17100	11700
28	29	11	-15300	9900
623	624	7	-15300	6300
949	950	11	-15300	9900
455	456	8	-14400	7200
1203	1204	14	-14400	12600
4	5	12	-13500	10800
1592	1593	10	-13500	9000
80	81	12	-12600	10800
1040	1041	6	-12600	5400
1297	1298	13	-12600	11700
1523	1524	9	-12600	8100
43	44	9	-11700	8100
249	250	11	-11700	9900
1260	1261	12	-11700	10800
1382	1383	11	-11700	9900
609	610	9	-10800	8100
2227	2228	9	-10800	8100
587	588	9	-9900	8100
751	752	9	-9900	8100
1199	1200	11	-9900	9900
1093	1094	6	-9000	5400
23	24	7	-8100	6300
732	733	7	-8100	6300
179	180	8	-7200	7200
1244	1245	7	-7200	6300
2123	2124	8	-7200	7200
2201	2202	5	-7200	4500
12	13	6	-6300	5400
59	60	7	-6300	6300
191	192	6	-6300	5400
771	772	7	-6300	6300

Figure 10: Table showing that volume selected for “Net gain” are the negative values

c. Right click “area” field and select statistics

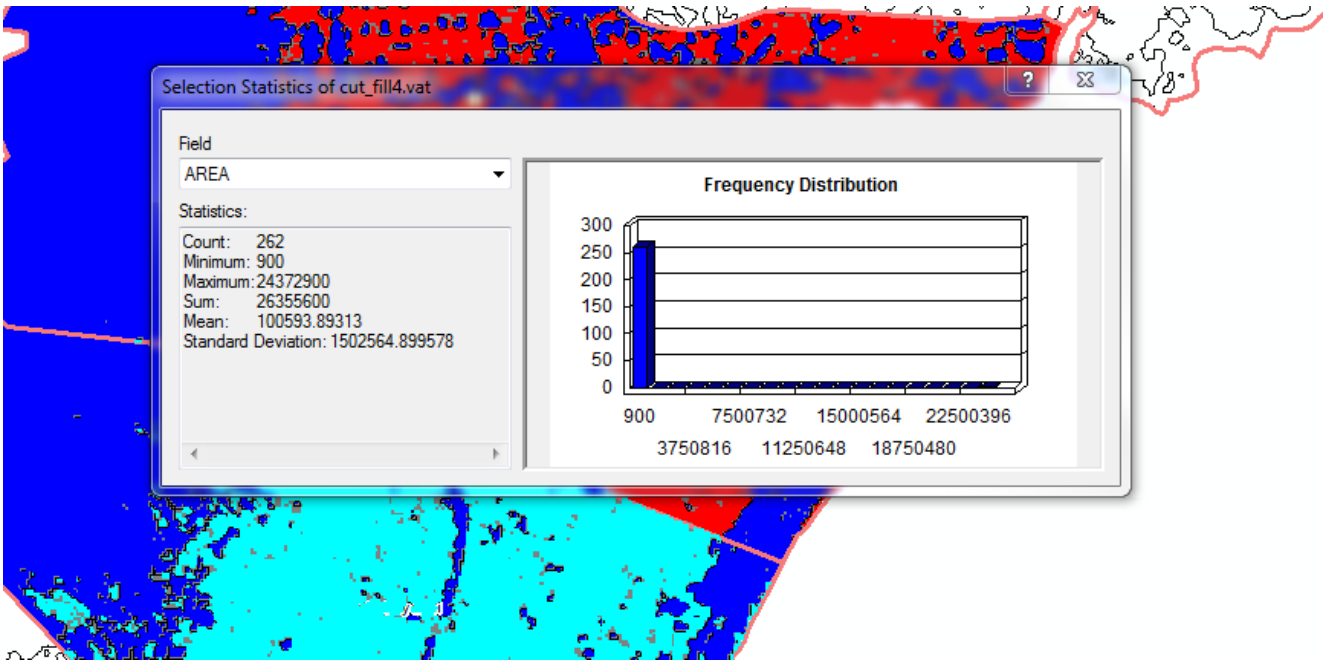


Figure 11: Showing the sum of the area affected by the 10 meter storm surges

d. This will tell you the sum of the area affected by the 10 meter storm surge
e. Make percentage of area affected by flood
    i. (Sum of area affected)/(Total area of ward) x100= Percentage of area affected by 10 meter storm surge
f. Multiply the "Percentage of area affected by 10 meter storm surge" by total population of the wards assuming even distribution of population, as calculated by "miya_cent" point file.
g. Do these steps (b-f) for both the Miyagino and Wakabayashi wards

Results:

Table of Calculated Populations affected in the Miyagino and Wakabayashi wards of Sendai, Japan

	Miyagino	Wakabayashi
Sum of Area affected by 10 meter storm surge	20.8161 km²	26.3556 km²
Total area of ward	58.1 km²	50.69 km²
Percent area affected by storm surge	35.83%	51.99%
Population of ward	190,473 people	132,306 people
Population affected by 10 meter storm surge	**68,247 people affected**	**68,786 people affected**

From this project, I have concluded that 68,247 people were affected by 10 meter storm surge of the Great Sendai Earthquake in Miyagino and 68,786 people were affected in Wakabayashi. Totaling to 137,033 people.

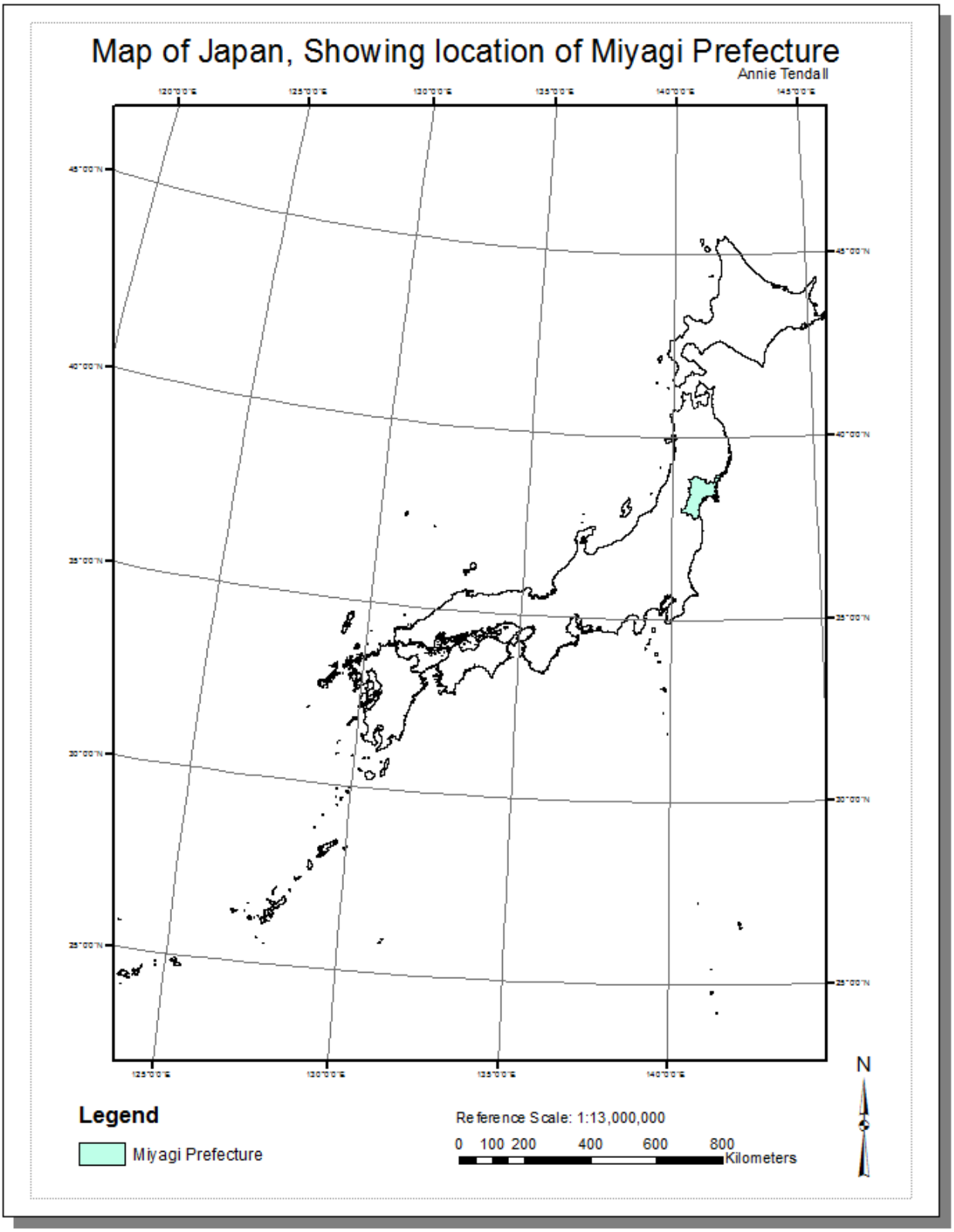
This number is a good estimate for the population affected but several factors must be accounted for that could change the actual populations affected. The assumption I made that the population was evenly distributed throughout the wards is one source of error, in reality, the population density is greater on the coast of Japan. This alone would mean that my population calculated could be smaller than the actual number. Another source of error in my calculation is the assumption made that there is a constant 10 meter storm surge. Some areas are going to have had storm surges higher and lower than the 10 meters I calculated the populations affected with. I also used a 2010 census for population values, so the actual number will be slightly different than what I calculated with.

I looked for data online to compare my numbers with, and found death tolls, numbers of houses damaged and things of that nature but was not able to find exact numbers of populations affected in the Miyagino and Wakabayashi wards of Sendai, Japan.

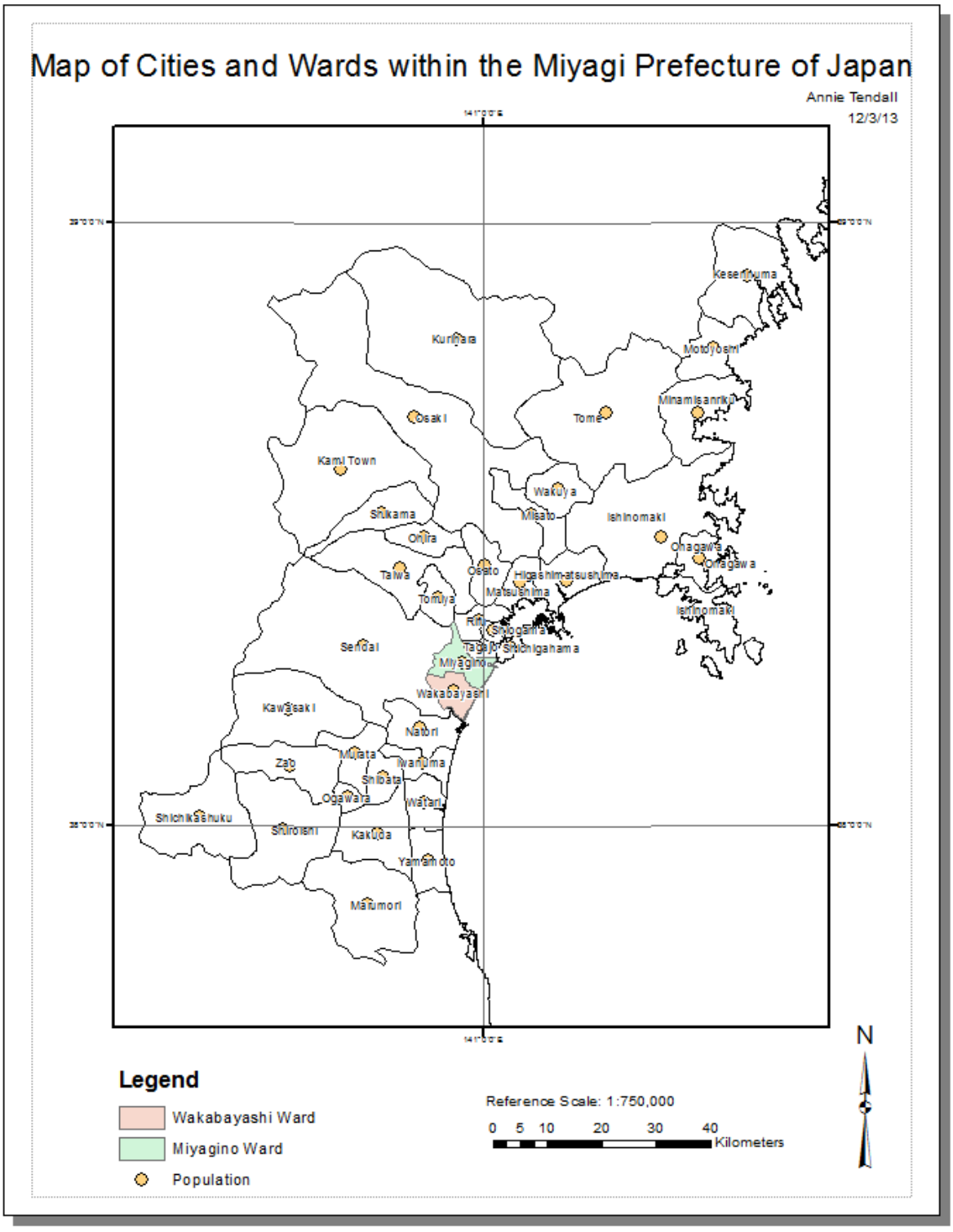
Overall, my calculations do represent the horrific damage and catastrophic effects the Great Sendai Earthquake had on the people of Japan, as seen by the large number of people that were affected by the 10 meter storm surge.

Deliverables (Maps)

1. Basic map of Japan to show location of Miyagi Prefecture



2. Map of Cities and Wards within the Miyagi Prefecture of Japan
    a. To show location of Miyagino and Wakabayashi wards of Sendai



3. Final Product Map: Showing the areas above and below the 10 meter storm surge in Wakabayashi and Miyagino Wards of Sendai, Japan following the Great Sendai Earthquake of 2011